BONUS! 2008 GUIDE TO SKY EVENTS

December 2007

Astronomy®

The world's best-selling astronomy magazine

Does life exist *on this* exoplanet?

Just 10 light-years away, the Sun-like star Epsilon Eridani anchors a system that contains the seeds of life p. 44

Why is the solar system cosmically aligned? p. 38

Hot observing sites in the United States p. 96

Sun-like star Epsilon Eridani hosts a planetary system that may have something in common with Earth — life.

PLUS:

15 tips for observing Mars p. 92

Earth's fiery start p. 32

Large Binocular Telescope opens its eyes p. 74

Tour the sky's reddest stars p. 82

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Vol. 35 • Issue 12

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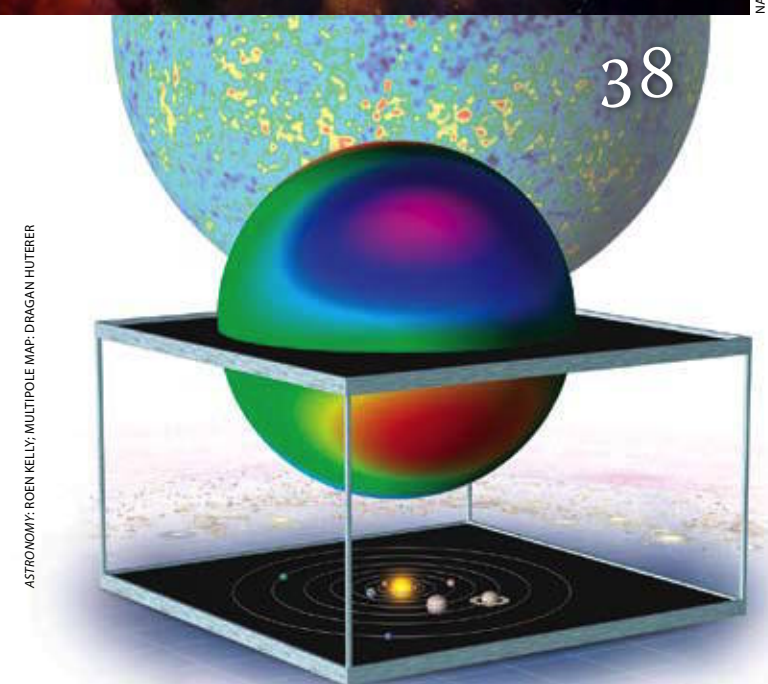
NASA/JPL-CALTECH/T. MEGEATH (UNIVERSITY OF TOLEDO) AND M. ROBBERTO (STScI)



ASTRONOMY: ROEN KELLY; MULTIPOLE MAP: DRAGAN HUTERER

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The world's best-selling astronomy magazine

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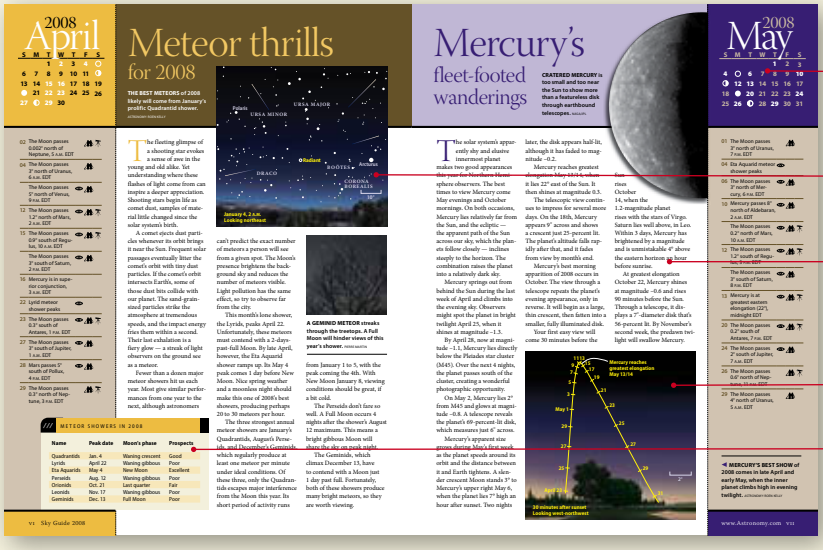

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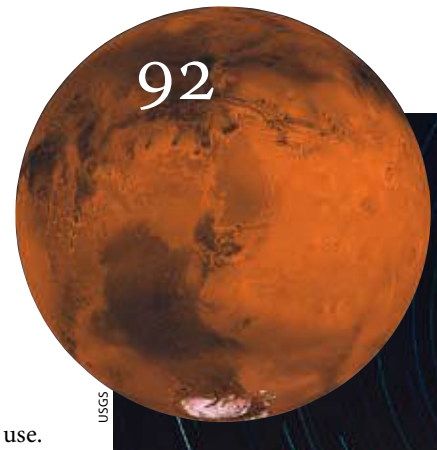
LARGE BINOCULAR TELESCOPE CORPORATION (LBTC)/JOHN HILL



USGS

TONY HALLAS

WEB EXTRA Visit **Astronomy.com/toc** for bonus material — it's exclusive to *Astronomy* magazine subscribers. Check out the new Astronomy.com in November.

BY DAVID J. EICHER

Visit the new Astronomy.com

Be sure to check out Astronomy.com, *Astronomy* magazine's web site, over the coming weeks. If you're not already a regular visitor to the site, you'll have a real treat in store. If you are a frequent browser of Astronomy.com, you'll be extremely delighted with upcoming changes.

In November, Astronomy.com will re-launch with a major redesign that will take the leading astronomy web site to new heights. We've added many new features that will let you experience the subject of astronomy like never before.

Our new home page boasts a beefed-up news section that will be the web's best place for astronomy news. We've added more staff-produced videos on astronomical news, observing, product reviews, and how-to tips that will get you more involved in the hobby.

Further, we will inaugurate several major features that will make Astronomy.com the most useful site for skywatchers. Our sky almanac feature, "Tonight's sky," will show you all the important observing data for your location every day, in real time. Rise and set, phase, and disk data for the Sun and Moon, visibility of planets, and major sky events will all be visible at a glance, customized for your part of the world.

We'll also unveil our interactive star map, "StarDome." Spending a few minutes with this new feature will convince you it is the Internet's best star map. StarDome offers greater interactivity than other web-based star maps. Astronomy.com will offer a version of this fantastic tool to everyone, and a more feature-rich version, StarDome Plus, reserved for subscribers only.

But that's just the beginning. We will also unveil another subscriber-only feature that's unlike any other. "Star Atlas," our web-based interactive all-sky atlas, provides a zoomable star atlas with 45,000 stars down to magnitude 8.0 and more than 1,000 deep-sky objects — all just a mouse-click away. There's nothing else like it on the web.

We will continue to feature blogs written by *Astronomy*'s editors, along with podcasts, reader forums, equipment reviews, polls, and information on the magazine and special issues. We'll present background stories on astronomy for kids, getting to know the sky, and how to observe from urban skies, as well as an astronomical glossary. In short, this is the web's deepest astronomy site.

Many additional features will be reserved for *Astronomy* subscribers: The Sky this Month; columns from our unsurpassed experts Bob Berman, Glenn Chaple, Phil Harrington, and Stephen James O'Meara; Ask Astro; and web extras that provide observing tips, news, and field reports.

Astronomy's staff has worked tirelessly in this redesign. In particular, Senior Editor Frank Reddy, Associate Editor Laura Baird, and Assistant Editor Jeremy McGovern have done tremendous work in this effort.

I know you will greatly enjoy the new Astronomy.com. Please let us know what you think at letters@astronomy.com.

Yours truly,

David J. Eicher
Editor

Astronomy

Volume 35, Number 12
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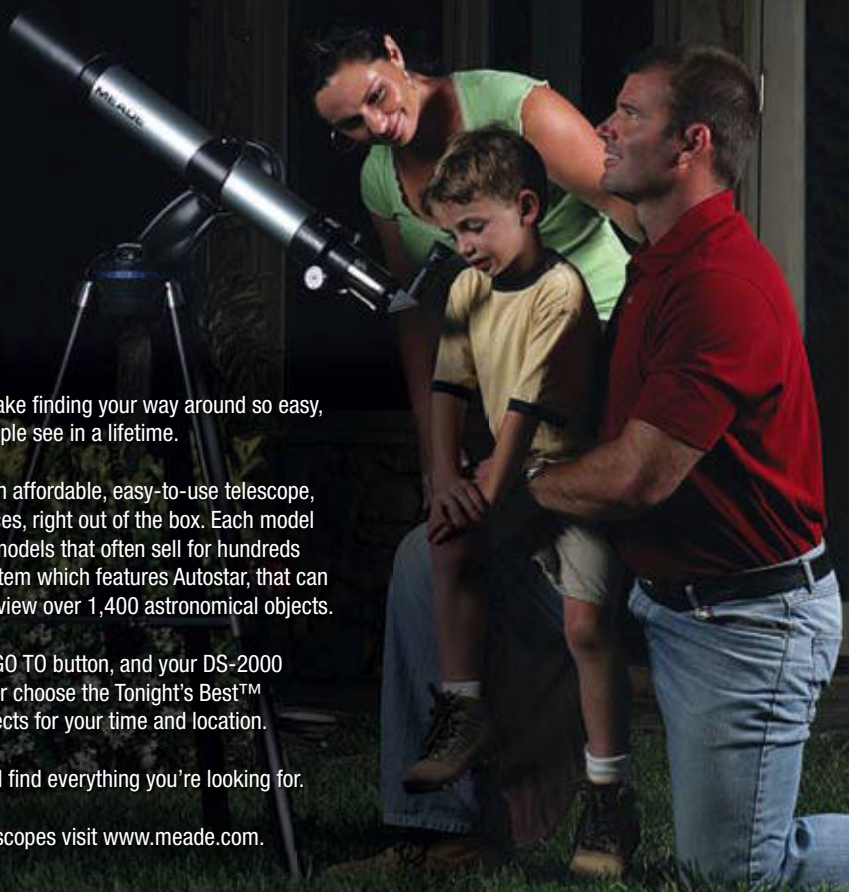

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Naval Observatory visit remembered

Geoff Chester's article about the U.S. Naval Observatory (August 2007) brought to mind a cherished memory. My dad took a business trip to Washington in 1968 and invited my mother and me along for the ride. Knowing we were to visit our congressman, I asked, "Do you think he might be able to get us in to see the U.S. Naval Observatory?" "Don't you dare ask," Dad sternly told me. But when the congressman greeted our family he said, "If there is anything I can do while you are in D.C., don't hesitate to ask."

Much to Dad's dismay, I did not hesitate to ask. Thanks to the hospitality of the astronomers at the observatory and to a wonderfully clear night sky, we were given a special tour of the observatory and observed Saturn in its glory.

Dad died in 1999. During his last 2 weeks of life, I sat with him in his hospital room.

In the wee hours of one morning, he began to talk about what a great life he'd had and some of the things we'd done together. He smiled broadly as he said one more time, "You know, I'll never forget being at the U.S. Naval Observatory and looking at Saturn through that telescope." — **MAYNARD PITTENDREIGH,** LAWRENCEVILLE, GEORGIA

Douse the light

I'd like to invite all astronomy club members to join the International Dark-Sky Association (IDA). Increasingly, light pollution threatens astronomers' observing sites The IDA raises awareness about light pollution's problems and solutions.

You can help by supporting the IDA. Until November 30, 2007, the IDA will offer a discounted $20 one-year membership exclusively for astronomy club members.

For more information, visit www.darksky.org/support/membership.php or call us at 520.293.3198. — **ROBERT L. GENT,** president of the International Dark-Sky Association's Board of Directors

ASAPH HALL discovered Mars' moons Phobos and Deimos with the USNO's Great Equatorial refractor. USNO LIBRARY

Black-hole jets

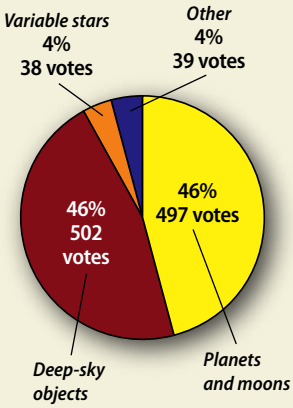
I found your special edition *50 Greatest Mysteries of the Universe* both interesting and educational. However, in "Can light escape from black holes?" you explain that nothing, not even light, can escape from inside a black hole. But in "How common are black holes?" you say huge jets of material escape from them. These two descriptions appear to contradict each other. How can both be true? — **PHILIP WITHERS,** SOUTHAMPTON, ENGLAND

It is true that no electromagnetic radiation, including light, can escape from inside a black hole's event horizon. However, the gas jets originate outside the event horizon, in the black hole's accretion disk of material spiraling inward. — **FRANCIS REDDY,** ASSOCIATE EDITOR

We welcome your comments. Send letters to Astronomy *Letters, P. O. Box 1612, Waukesha, WI 53187; e-mail to letters@astronomy.com. Please include your name, city, state, and country. Letters may be edited for space and clarity.*

Online poll results

POLL QUESTION:
What is your favorite telescope target?



Total votes: 1,076

Join the fun! Each week, Astronomy.com posts a poll question for visitors to answer. You can find the question on the lower right side of the home page.

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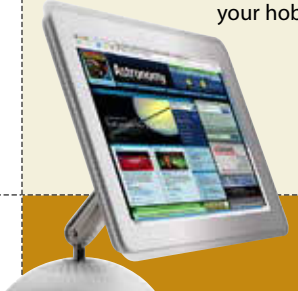

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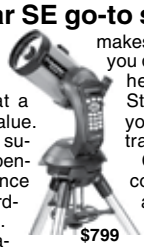

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The compact 92mm f/5.5 **TMB-92** triplet, below, fills the void left by the discontinued 90mm Astro-Physics Stowaway (a legendary scope that sells for up to $6000 used). But you won't pay $6000 for the TMB-92. This fast focal ratio TMB apo refractor is only $1999. The TMB-92 has a collimatable lens cells and a famous *Feather Touch* 2.7" dual-speed rotating rack and pinion focuser.

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A cosmic mixmaster

Galaxies rarely exist in isolation. Most belong to groups or clusters, but few such gatherings match the beauty of the Hercules cluster (Abell 2151). Unlike most rich clusters, where ellipticals dominate, Abell 2151 holds quite a few spirals. You can tell them apart because the star-forming spirals have a bluish cast, while ellipticals look yellowish. Notice the many interacting galaxies in this cluster. The partially overlapping spirals NGC 6050 and IC 1179 lie just left of center. And the warped disk of the edge-on spiral NGC 6045 (right of center) is a direct result of a past interaction. Abell 2151 lies some 500 million light-years from Earth and forms part of an even larger supercluster. CFHT/JEAN-CHARLES CUILLANDRE/COELUM

BY BOB BERMAN

End of the world: 2012

Every few years, a crackpot comes

forward with a new "Armageddon from space" theory to scare those who performed poorly on the SATs. The current version has the doomsday clock ticking down toward the 2012 winter solstice — 5 years from now. Because this prediction has already spawned more than 100 books, astronomers might want to know enough about it to answer any questions.

This is nothing new. Some may be old enough to remember when Orson Welles' radio show gave Martians a bad rep. John Gribbin and Stephen Plagemann's 1974 book *The Jupiter Effect* warned of a 1982 mega-quake caused by the planets lying on one side of the Sun, throwing it off balance. New Age communes almost ran out of prayer beads as the date approached. Result: Nothing happened.

The crazies usually come out for major astro-events. In 1997, Comet Hale-Bopp inspired 39 suicides within a cult that believed an incoming alien spacecraft lurked behind the comet.

The approach of each new century brings a tradition of dread, but forecasts of calamity got an added boost the last time around thanks to Y2K. Result: Nothing happened.

Nothing ever happens. When Earth does get clobbered by something big from space, it comes without warning.

We can often attribute prophesies of doom to lost civilizations or mysterious geniuses. The biggie was Nostradamus. Anyone who wants to muddle through his endless obscure verses, called quatrains, should buy an erudite translation like the one by Liberté E. LeVert, since Nostradamus wrote in archaic French that was abstruse in the 16th century. The quatrains, arranged in "centuries" that have nothing to do with actual time, contain countless lines like, "Burned by thunders, at 23 the sixes, the foolish woman shall fall from high places."

Nostradamus' followers create retrospective prophesies from his drivel by mixing and combing lines from several quatrains. Numerous editions have already altered lines to better conform with world events. It's a hoot to search through the rambling verses for anything that remotely matches current headlines and then simply omit all irrelevant or contradictory lines.

WHEN EARTH DOES GET clobbered by something big from space, it comes without warning.

The process is still alive and well with the supposed Mayan ability to predict the end of the world.

Of course, scholars insist the Maya said no such thing. The various Mayan calendars merely had different cycles — the longest resembling our own millennium ending and a new one starting. Nothing momentous accompanied such time-keeping — the cycles were like the Sun rising and setting.

But now the fun begins, as people come up with exquisitely moronic astrobabble in an attempt to find something celestial that might happen as the Mayan long count clicks over like a car's odometer. And bingo: Earth's orbit makes the Sun pass in front of the galactic plane, the Milky Way, twice a year, every June and December.

Some web sites claim the Sun passes right in front of the galaxy's center, but that never happens — our orbit isn't tilted that way. In any case, the scare literature claims stars lying beyond the Sun will channel some sort of unspecified "energy" our way. No matter that nothing ever happened before when the Sun crossed the galactic plane. Nor does anyone explain why the distant background should matter to begin with. Do we care if a friend stands in front of a parked car instead of a tree?

But this year, the Sun crosses the galactic plane December 21 — the day of the solstice. So what? Well, the fact that winter or summer begins will supposedly block (or maybe enhance) this "energy" for some reason. According to a Belgian "researcher," this will "reverse the magnetic fields of the Sun, causing it to become 10 to 20 times hotter, which will reverse Earth's rotation on its axis, and flood its inhabitants."

That's a wild day at the factory. No web site explains the supposed mechanism for this bizarre chain of impossible events, except by invoking imaginary, rather than actual, astronomy. We simply must trust that the Maya figured all this out during their free time, when they weren't tossing their citizens from pyramids.

So, now you know the 2012 doomsday story. And if you flunked earth science, you probably won't bother showing up for work that day.

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BY GLENN CHAPLE

Nine eyepiece questions answered

I receive many inquiries about eyepieces. These questions range from getting more power out of a scope to the meaning of eyepiece nomenclature to recommendations for eyepieces for various deep-sky objects. This month, I'll address several beginners' eyepiece questions.

What does an eyepiece do?

An eyepiece magnifies the image produced by the telescope's objective lens or mirror. Besides differences in focal length and optical design, eyepieces come in three standard barrel diameters. The smallest (0.965 inch) have fallen in favor of the 1¼" size found on most telescopes. In recent years, owners of large-aperture scopes have moved to huge 2" eyepieces.

How many eyepieces do I need?

You'll need at least two. The first eyepiece, for low-power/wide-field views, helps locate targets and observe large-scale deep-space objects, such as the Pleiades. Then you'll need a second eyepiece, with moderately high magnifications for lunar and planetary observing and studying compact deep-space objects, such as planetary nebulae.

How can I determine the magnifying power of an eyepiece?

Divide the telescope's focal length by the eyepiece's focal length. For example, using a 10mm eyepiece with a telescope whose focal length is 1,250mm yields a magnification of 125x. The lower the eyepiece's focal length, the higher the magnification it produces.

Eyepieces with focal lengths of 10mm or less are considered high-power. Low-power eyepieces have focal lengths greater than 20mm. Eyepieces between these focal lengths produce mid-range magnifications.

SELECT EYEPIECES based on what's important when viewing the sky through your scope. These preferences might include a wide field of view, pinpoint star images, or planetary contrast. *ASTRONOMY:* JAMES FORBES

What is the highest power I can get with my telescope?

Under average seeing conditions, the highest magnification that still provides a crisp image is 25–30x per inch of your telescope's aperture. On those rare nights when the atmosphere is ultra steady, you might double this limit. Seeing conditions hardly ever allow for magnifications beyond 300x, regardless of telescope size.

What is a five-element eyepiece?

Five-element eyepieces contain five lenses. The simplest eyepieces have two or three elements. Some designs have as many as eight. What type of eyepiece (and how many elements it employs) depends on what you are targeting. Multi-element eyepieces provide improved views over wide fields.

What is the lowest power I can get with my telescope?

Your scope's focal ratio has a lot to say about its low-power limit, but it's best not to go much lower than 4–5x per inch of aperture.

How do I determine an eyepiece's field of view?

Divide the eyepiece's apparent field of view — the angular diameter of the bright circle seen when you place the eyepiece in front of your eye and look toward a light source — by the magnification it produces with your telescope. A 50° apparent-field-of-view eyepiece magnifying 50x will cover 1° of sky, about 2 Moon-diameters.

Is the eye relief of an eyepiece important?

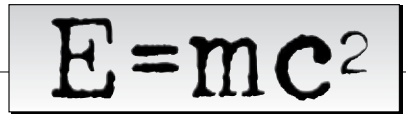
Eye relief is how far from the eyepiece you need to place your eye in order to glimpse the entire field of view. Eye relief is especially important if you wear eyeglasses. Using an eyepiece with poor eye relief means pressing your eye against the eyepiece, which is impossible if you wear glasses.

What eyepieces do you recommend for my telescope?

Aha! That's the million-dollar question. Like selecting a car or golf clubs, choosing an eyepiece is a personal decision.

What type of instrument do you own? What sky objects do you prefer to view? How much will you spend? There are basic guidelines as to what eyepieces will perform best in your telescope. In the end, the only way to know how an eyepiece will perform is to slip it into your scope, aim skyward, and look!

Einstein Deciphered the Puzzles of the Universe for Every Scientist in the World. Isn't It about Time Someone Deciphered Them for You?



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About Your Professor

Dr. Richard Wolfson (Ph.D., Dartmouth College) is Professor of Physics at Middlebury College in New England. Decades of teaching at Middlebury, with its strong emphasis on the humanities, have made him an expert at demonstrating the logic and significance of physics to students from many fields. His writings have appeared in *Scientific American*. He is author of *Physics for Scientists and Engineers*.

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Offer Good Through: December 28, 2007

BY PHIL HARRINGTON

Winter's swarming fireflies

Many a night I saw the Pleiads / Rising thro' the mellow shade / Glitter like a swarm of fire-flies / Tangled in a silver braid. — Alfred Lord Tennyson, *Locksley Hall*.

Tennyson's poem mentions my favorite binocular open star cluster: the Pleiades (M45). We can all enjoy his imagery this month as M45 rises high in our late autumn sky. Is there any object more beautiful than the sapphire-blue stars of the Seven Sisters glistening through binoculars?

Many cultures knew M45 long before the invention of binoculars, however. Ancient Chinese annals written around 2357 B.C. refer to the Pleiades.

The earliest written record of this cluster in Western culture dates to about 750 B.C., when Homer wrote about the Seven Sisters in the *Iliad* and *Odyssey*. Three passages in the Old Testament also cite the open cluster by name. In Job 38:31, for instance, God asks, "Can you bind the chains of the Pleiades, or loose the cords of Orion?"

Greek mythology first introduced the Pleiades as the Seven Sisters. All were offspring of the titan Atlas and ocean nymph Pleione. Even today, the stars bear the names of the mythological sisters and their parents.

The six brightest stars in the Pleiades create a tiny dipper, with father Atlas forming its handle. His daughters Alcyone, Merope, Electra, and Maia represent the bowl, while Taygeta marks the tip of a pouring spout just west of Maia. Completing the family portrait, sister Celaeno rests between Taygeta and Electra, Asterope is just north of Maia, and mother Pleione sits northeast of Atlas.

Some 440 light-years from Earth and about 20 light-years across, the Seven Sisters may be no older than 100 million years. All told, at least 500 stars scattered across 2° — 4 times the diameter of the Full Moon — belong to the group.

The Pleiades hold many double and multiple stars. For instance, parents Atlas and Pleione form a wide pair in binoculars, while Asterope is a pair of 6th-magnitude stars that's easily observed.

Several strings of fainter stars are woven throughout the cluster. One especially noticeable queue of five stars stretches southeastward from Alcyone, like distant cousins.

On an exceptionally clear evening, you may actually see a hint of Tennyson's "silver braid" or faint interstellar dust surrounding some of the brighter stars. For years, astronomers assumed these clouds were the remains of the nebula that bore the cluster. Recent studies, however, show the clouds and the cluster move in different directions and are currently just passing through one another.

The brightest portion of the Pleiades nebulosity, NGC 1435, encircles Merope and extends south. Many stargazers are fooled into thinking they've seen the nebulosity when they notice a bright glow around each of the brightest Pleiades.

What they are really seeing is starlight scattering inside their binoculars. To make sure you're glimpsing the real thing, check the nearby Hyades open star cluster. If you also see nebulosity there, where there is none, then your binoculars are either fogged or may need cleaning.

If you have questions or comments, e-mail me at phil@philharrington.net.

WHEN SPYING M45, most naked-eye observers can count four to six stars arranged in the shape of a dipper. Slightly darker skies will reveal a seventh star. TAD DENTON/ADAM BLOCK/NOAO/AURA/NSF

WEB EXTRA You'll find more on M45, a binocular tutorial, and observing targets at www.Astronomy.com/toc.

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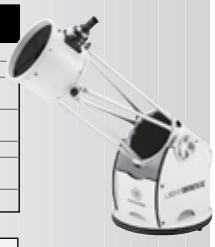

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BY STEPHEN JAMES O'MEARA

The Crystal Palace

As we stand on winter's doorstep, keep your eye on the daytime sky. Now is the time when high-level clouds regularly appear. It's also when sunlight interacting with clouds' ice crystals can produce a wide variety of colorful sky phenomena. So let me introduce you to the

"Crystal Palace" of daytime wonder. We'll start with the palace's brightest components: the 22° halo around the Sun and its companion sundogs: patches of light that resemble the Sun. As Barry Lopez notes in his 1986 best-selling book *Arctic Dreams*, "Seeing them … is largely a matter of training yourself to look."

Training begins by keeping vigil for feathery cirrus clouds or the frosty glaze of cirrostratus clouds. Both form at an altitude of about 20,000 feet (6,100 meters), where the air temperature is below freezing. Consequently, countless microscopic ice crystals form and produce the prismatic effects we're examining this month.

The most common is the Sun's 22° halo, produced when sunlight passes through hexagonal, pencil-shaped ice crystals, which act like 60° prisms. Orient these crystals in every direction across the sky, and you'll see a beautiful light ring centered on the Sun with a 22° radius. That is about the width of your outstretched hand, from thumb to pinky, held at arm's length. It helps to block the Sun with your hand or a foreground object. Sunglasses will cut down on glare and enhance any display's colors.

Halos can occur any time of the day and last from minutes to hours. The most striking and colorful displays occur when near-invisible "stealth" cirrostratus move in just before a warm front. The presence of such clouds can easily elude a lazy eye.

Once you sight a halo, watch out for little devils in the detail. The ever-changing abundance, distribution, and orientation of crystals across the sky can affect a halo's overall appearance. At any given time, a section of the halo can fade in and out of view, giving the ring an inconsistent luster. A partial halo also may occur. Without using critical thought, the uninitiated might mistake such an arc for a rainbow.

From temperate latitudes, halos, or fragments of halos, occur with surprising frequency, even if for only a short period of time. Constant vigilance is the key to seeing them. While halos appear more frequently over temperate regions, especially during the cool winter months, they can occur at any time of the year over any location on Earth — even over the hot tropics. It's the altitude of the cirriform cloud, not the latitude of the observer, that matters.

The halo's inner edge is a reddish-orange tint, while its outer edge looks bleached blue. When light passes through a prism, all of the rays are refracted by degree, with blue light being refracted the most. That's why the outside edge of the halo, which is farthest from the Sun, is blue. Because the minimum deviation angle — the angle through which light is bent by a reflecting, refracting, or polarizing element — passing through a rotating hexagonal crystal is 22°, any crystals lying

THIS 22° HALO, imaged from O'Meara's backyard in subtropical Hawaii last summer, is a good example of a colorful, but nonuniform, halo. STEPHEN JAMES O'MEARA

NOTE HOW THE SKY immediately inside the Sun's halo is slightly darker than the region just beyond the ring's outer edge. STEPHEN JAMES O'MEARA

inside the halo's inner edge cannot contribute light to the display.

Crystal dogs

Not all hexagonal ice crystals are cylindrical. Some are flat, hexagonal plates. Plate crystals fall from elevation with their long faces angled slightly to the horizon, like leaves falling in a gentle breeze.

Because these crystals don't have random orientations in the sky, we see light refracting from their sides only when the Sun is at an altitude of about 60° or lower. Catch a nice alignment of sunlight and plate crystals, and suddenly "sundogs" accompany the 22° halo. These two intense orbs of colored light, one on either side of the halo, show up at the same altitude as the Sun.

Some astute observers know 22° halos and sundogs frequently appear together. But sundogs aren't part of the 22° halo. Unless the Sun is directly on the horizon, the only time sunlight can pass symmetrically through a plate crystal, sundogs always appear to the halo's side. The higher the Sun sits in the sky, the greater the distance between the halo and a sundog.

When the Sun is more than 60° above the horizon, refracted rays from plate crystals can no longer reach the observer's eyes so the sundog vanishes. Few observations of sundogs at elevation greater than 40° exist.

In this page's top photograph, note the sundog's comet-like tail. It is another phenomenon known as the parhelic circle. The sides of hexagonal ice crystals reflect (not refract) sunlight like little mirrors. Sometimes light from these reflections completely circle the sky at the same altitude as the Sun.

But notice how the tails seem to curve upward in the bottom image. This illusion — the curvature of a line at constant elevation — is easily illustrated.

Imagine standing inside a large horizontal ring. If you center the ring in your eyes, the section you see will appear as a straight line. But if you lift the ring directly over your head and look up, you'll see the same section suddenly curved.

Seeing daytime phenomena will make you a better nighttime observer. Skywatchers observe, day and night. The more you practice, the more you'll see — it's that simple.

A SUNDOG is scientifically referred to as a parhelion, but also is commonly referred to as a mock Sun or false Sun. Sometimes, sundogs can rival the Sun in intensity. STEPHEN JAMES O'MEARA

SUNDOGS can splinter into a spectrum of intense colors and have comet-like tails. This one is about to be transited by a hawk. JORGE FIGUERORA

TWO SUNDOGS (arrows) rest about 5° off the Sun's halo. The Sun has an altitude of 40°. The clouds eventually thickened, and the phenomena disappeared. STEPHEN JAMES O'MEARA

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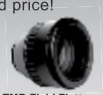

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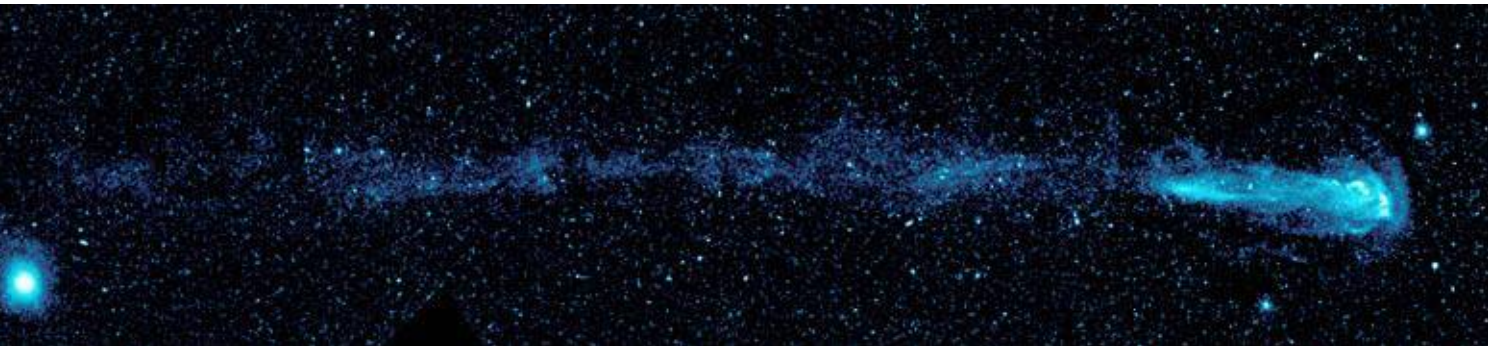

IT'S A BIRD! It's a plane! It's a tail of warm gas trailing from Mira. This ultraviolet image is the first of a star with a comet-like tail. NASA/JPL-CALTECH

Ultraviolet images reveal Mira's tail

One of the sky's most frequently observed stars can still surprise astronomers: Mira, a variable star in Cetus, sports a comet-like tail of hot gas behind it.

Mira is a favorite target for amateur and professional observers alike. New ultraviolet images from NASA's Galaxy Evolution Explorer revealed Mira's tail. A team of astronomers led by Caltech's D. Christopher Martin reported the find August 16 in *Nature*.

Mira cruises through space at the speedy pace of 291,000 mph (468,000 kph), probably the result of gravitational boosts from stars it has passed.

The red-giant sun, officially named Mira A, has a small, unseen white-dwarf companion, Mira B. The binary system lies 350 light-years from Earth.

Mira's tail is 13 light-years long — approximately 20,000 times the average distance from Pluto to the Sun — and about 30,000 years old.

Astronomers will probe the tail for clues to Mira's chemical history. **— DANIEL PENDICK**

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29 **Uranus' changing rings**

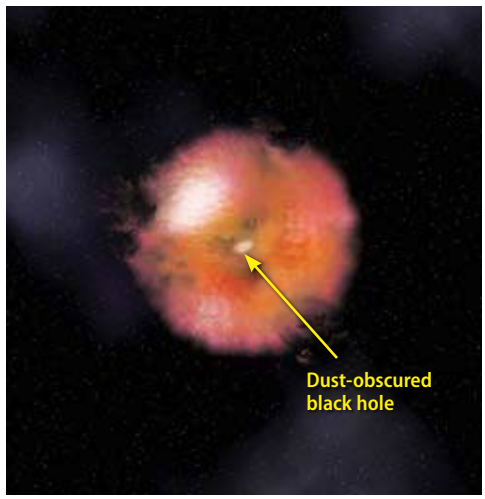
Stealthy galactic nuclei unveiled

Veils of dust obscure our ability to see some of nature's brightest beacons, a team of American and Japanese scientists discovered. Their observations appeared August 1 in *The Astrophysical Journal Letters*.

The energy-spewing beacons, called active galactic nuclei (AGNs), lie in the hearts of some galaxies. They include quasars, blazars, and Seyfert galaxies.

The scientists observed AGNs in two dust-obscured galaxies, ESO 005-G004 and ESO 297-018, using NASA's Swift telescope and the Japanese/U.S. Suzaku X-ray Observatory. The dust veils hide the AGNs from view with telescopes attuned to visible or ultraviolet light.

But by using X-ray telescopes, the team found formerly unknown AGNs in the heavily obscured cores of the two galaxies. The newfound AGNs are just as bright as other, more familiar types of AGNs. **— D. P.**



AURORE SIMONNET (SONOMA STATE UNIVERSITY)

HIDDEN HOLES. In this artist's depiction, dust and gas hide a black hole from many telescopes' views. Astronomers have now found hundreds of such deeply obscured galactic cores.

NASA/JPL-CALTECH; LORI ALLEN (CFA)/ GOULD'S BELT LEGACY TEAM

INFANTS UNVEILED. The Spitzer Space Telescope found a never-before-seen cluster of infant stars in the Serpens star-forming region, a cloud of dust and gas in the constellation Serpens Cauda. Green signifies hydrogen gas; red indicates organic molecules called polycyclic aromatic hydrocarbons.

Spitzer peers into a stellar nursery

While probing a star-forming cloud 848 light-years from Earth, the Spitzer Space Telescope unveiled a gaggle of 50 young stars. Thirty-five of them are protostars, indicating the cluster formed as recently as 100,000 years ago.

A team of astronomers headed by Robert Gutermuth of the Harvard-Smithsonian Center for Astrophysics discovered the star cluster, which they dubbed Serpens South.

Its older, larger, and more well-known neighbor is the Serpens star cluster (M5), containing 100,000 or more stars.

Additional observations with the Submillimeter Array radio telescope on Mauna Kea in Hawaii showed Serpens South and M5 move through space at the same speed.

"It could be that the cloud of material that produced the Serpens cluster and Serpens South are physically related, but we're just not certain yet that they are," says Lori Allen of the Harvard-Smithsonian team.

The team spied Serpens South during a broader survey of star-forming regions that Allen heads — the Gould's Belt Legacy Project.

Serpens South lies within a blanket of gas and dust from which no visible light can escape. Spitzer's infrared sensors detected thermal energy emitted by the young stars. **— D. P.**

QUICK TAKES

HIGH HOTEL PRICES
The Galactic Suites space hotel could open by 2012. The starry-eyed view includes 15 sunrises a day. Cost: $4 million for 3 days.

ROCK THE ROCK
NASA engineers explored a plan to use 1.2-megaton nuclear warheads to nudge dangerous near-Earth asteroids into safer trajectories.

EARLY BLOOMERS
Astronomers found galaxies barely 2 billion years old, blazing with star formation 1,000 times more intense than in today's Milky Way.

SUN SHOWERS
A recently discovered statistical link between peaking sunspot activity and heavy East Africa rainfall could improve flood forecasts.

SOLAR SING-ALONG
Seismic rumbles in the Sun induce vibrations in Earth via magnetic-field interactions, according to data from NASA's Ulysses spacecraft.

BIRTHDAY 'BOTS
The twin Voyager robotic space probes, launched in 1977, marked 30 years of continuous flight through the solar system.

COLD CLOUDS
The Large Bolometer Camera saw first light in June 2007 at a 12-meter telescope in the Chilean Andes. The camera images cold gas clouds.

SEE THE NEW MOON
NASA and Arizona State University premiered super-high resolution digital scans of historic Apollo images at apollo.sese.asu.edu.

G WHIZ!
Cassini spotted an icy arc that may feed Saturn's G ring. Interactions between the arc, micrometeors, and Saturn's magnetic field create particles to refresh the ring.

SPACE BUGS
The cargo returned to Earth August 21 on space shuttle Endeavour included space-grown pneumonia bacteria for study by Earth scientists.

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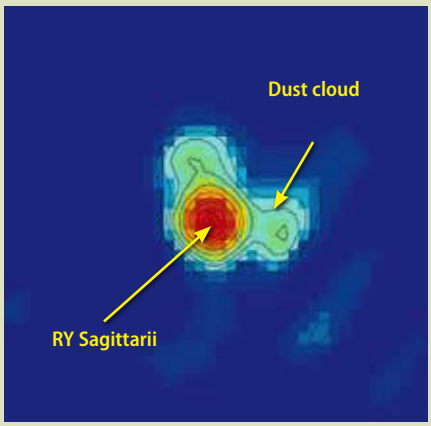
Stellar dust puffs scoped



ESO

DUST PUFFS. This image, created with the European Southern Observatory's Very Large Telescope, reveals dust clouds near the star RY Sagittarii. Dust outbursts explain the star's dramatic dimming.

French and Brazilian astronomers have detected a huge stellar dust puff that explains why some supergiant suns brighten and dim so dramatically. The team sighted the dust puff around RY Sagittarii, a star 6,000 light-years away in the constellation Sagittarius.

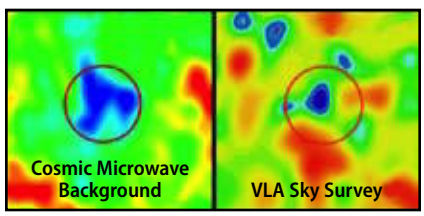
RY Sagittarii is a type of variable star that dims by a factor of 1,000 over the span of a few weeks and then slowly returns to its former brightness. The stars are thought to periodically cast off giant dust clouds that obscure their light, causing the dramatic dimming.

A team of astronomers led by Patrick de Laverny of the Observatoire de la Côte d'Azur in France trained the European Southern Observatory's Very Large Telescope Interferometer on RY Sagittarii. Combining light from its four individual scopes produced ultrasharp images.

The images revealed a dust cloud relatively close to RY Sagittarii — about 30 times the average distance between Earth and the Sun. In 2003, de Laverny and colleagues detected dust clouds near RY Sagittarii, but not in as great detail.

The astronomers plan to conduct additional observations in hopes of nailing down exactly which part of the star produces the dust. **— D. P.**

The hole in the sky



HOLY HEAVEN. At left, a "hole" in the constellation Eridanus shows up in microwave measurements by the WMAP satellite. At right, the hole appears as a gap in matter density, as measured by the VLA radio telescope. NRAO/AUI/NSF/NASA/L. RUDNICK, ET AL.

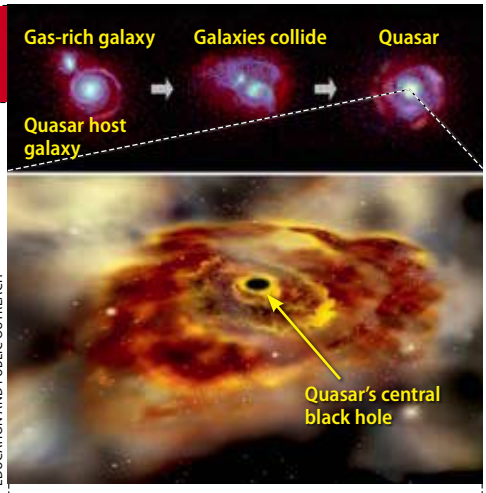
Astronomers pointed the Very Large Array (VLA) radio telescope at a patch of sky in the constellation Eridanus and found . . . nothing.

The "hole," 1 billion light-years across, appears to be devoid of both luminous (energy-producing) matter and dark matter, according to astronomer Lawrence Rudnick of the University of Minnesota and his colleagues. They reported the discovery in a paper to appear in *The Astrophysical Journal.*

The finding emerged from a VLA survey of the sky visible from the telescope's home in Socorro, New Mexico. The observations revealed a significant scarcity of galaxies in Eridanus.

The hole's location coincides with a similar "cold spot" in the temperature of the cosmic microwave background (CMB), as mapped in 2003 by the Wilkinson Microwave Anisotropy Probe (WMAP). The CMB is left over from the Big Bang and fills all of space.

Astronomers have detected similar CMB holes before, but the latest discovery is doubly surprising. "Not only has no one ever found a void this big, but we never even expected to find one this size," Rudnick says. **— LAURA LAYTON**



TOP: JOSHUA BARNES (UNIVERSITY OF HAWAII); BOTTOM: AURORE SIMONNET (SONOMA STATE UNIVERSITY)/NASA EDUCATION AND PUBLIC OUTREACH

HOSTILE TAKEOVER. **In a computer simulation (top), the merger of two galaxies forces hydrogen and helium to a quasar's central powerhouse: a black hole.**

Galactic gas gobbler

Quasars can radiate a billion times the Sun's energy, but what supplies gas to fuel the massive black holes that power them? A report in the August 1 issue of *The Astrophysical Journal Letters* points to cosmic crack-ups between galaxies.

Quasars, at the center of some giant galaxies, consist of a black hole with a disk of gas spiraling down into it. Astronomers hypothesized that the collision of the quasar host and a second galaxy could drive fresh fuel to the central back hole.

Astronomer Alan Stockton and graduate student Hai Fu at the University of Hawaii in Manoa analyzed the spectra of 12 quasars. They found the gas feeding the quasars' central black holes is nearly pure hydrogen and helium.

This means the gas didn't originate in a quasar's host galaxy, which is laced with heavier elements like carbon and oxygen. So where does the uncontaminated gas come from?

Stockton and Fu argue that the gas must come from a galaxy in the process of merging with the quasar's host galaxy. "Our results provide the first direct observational evidence that the gas from a merger can indeed be driven down to the immediate vicinity of the central black hole," they conclude. — **D. P.**

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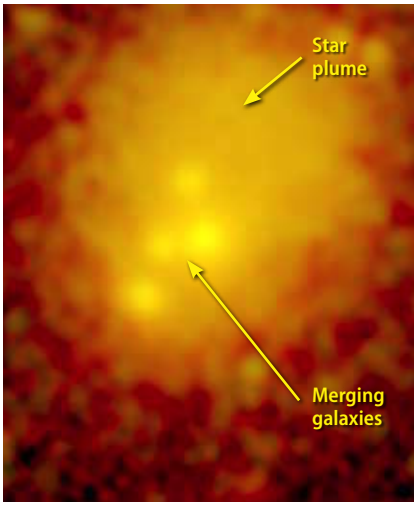

NASA/JPL-CALTECH/KENNETH RINES (CfA)

COLLISION COURSE. **A four-way galactic merger will evolve into one of the most massive galaxies in the universe.**

Cosmic crack up revealed

During a routine survey with the Spitzer Space Telescope, a team of astronomers stumbled across the birth of a supergalaxy. It's the first merger of four large galaxies ever seen, according to a report to appear in the *The Astrophysical Journal Letters.*

While observing a star cluster 5 billion light-years from Earth, Kenneth J. Rines of the Harvard-Smithsonian Center for Astrophysics and colleagues spotted a fan-shaped plume of billions of stars. The star plume led the astronomers to ground zero for the merger of four blob-shaped (elliptical) galaxies.

Three of the galaxies contain about the same mass as the Milky Way; the fourth has 3 times its bulk. Eventually, the merger will culminate in a single galaxy 10 times the mass of our own.

The star plume is the result of forces unleashed by the merger. Eventually, many of the stars will gravitate back into the new supergalaxy.

However, no new stars are being formed at the moment due to an apparent lack of gas among the merging galaxies to fuel stellar birth. **— D. P.**

SMART-1 returns Moon pictures

The European Space Agency's SMART-1 satellite imaged lunar features that will help scientists reconstruct the geologic history of the Moon's giant basins. Favorable lighting from the Sun and SMART-1's low elevation helped the spacecraft capture fine contrasts in lunar surface features.

For example, SMART-1 imaged strike-slip faults in the Humorum basin. Strike-slip faults mark a boundary at which one crustal fragment, or plate, slides past another.

Stefan Peters, of ESA's European Space Research and Technology Center, and his colleagues, presented the SMART-1 observations August 22 at the European Planetary Science Congress in Potsdam, Germany. **— L. L.**

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CLEAR VIEW. **Smart-1 snapped sharp views of the lunar surface.**

BRIEFCASE

Light pollution

Chemical clues discovered in a white-dwarf star's spectrum suggest an asteroid fell into the star, "polluting" its outer atmosphere. The relative amounts of elements in the polluted star are similar to those of Earth and the Moon, suggesting the star could develop rocky planets. **— D. P.**

Planet lite

Astronomers at Lowell Observatory in Flagstaff, Arizona, spotted the largest exoplanet with a confirmed diameter. The planet is 70-percent larger than Jupiter, but less massive. The planet's low density means it would float in water. **— D. P.**

Giant hunting

A research team at Pennsylvania State University in College Park discovered a planet orbiting a red-giant star. It's the first success in a new effort to search 1,000 red-giant stars for exoplanets. Studying such planetary systems may provide clues to what fate awaits our solar system in 5 billion years, when the Sun swells into a red giant. **— D. P.**

25 years ago in *Astronomy*

December 1982

Yerkes Observatory in Williams Bay, Wisconsin, is home to a 40-inch refractor — the largest in the world to date. Since astronomers first made observations there in 1897, scientists have revered Yerkes for its modern approach to studying the stars.

Historian Bruce Bond took readers on a journey through the famous observatory's past in the December 1982 *Astronomy* feature article, "A celebration of light: Yerkes in perspective."

George Hale, a professor of astrophysics at the University of Chicago, designed Yerkes as a union of telescope observation and laboratory research. With its powerful refractor and a respected staff, it became the most advanced astrophysical observatory of its day.

December 1997

10 years ago in *Astronomy*

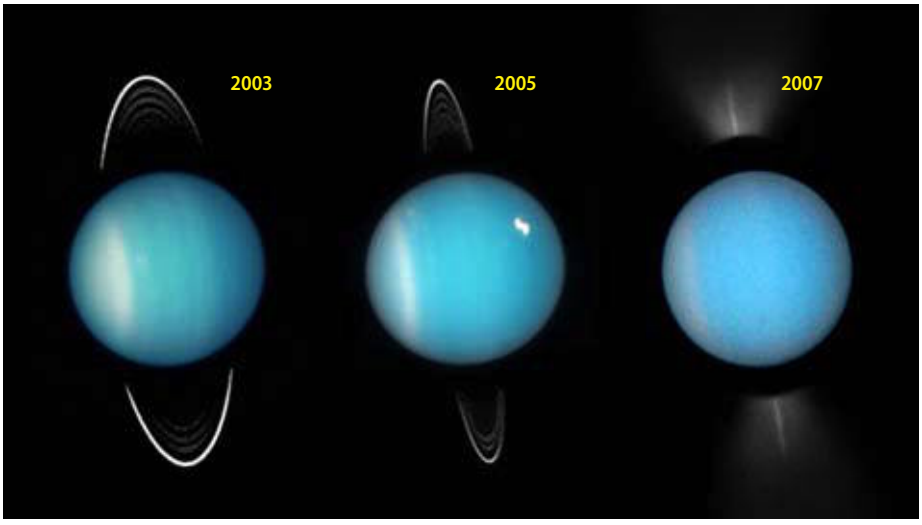
For most of his career, astronomer Allan Sandage fought a lonely battle in the debate over the universe's rate of expansion. Frederic Golden profiled Sandage, "Astronomy's feisty old man," in the December 1997 issue.

The fight began after Edwin Hubble discovered the expansion of the universe in 1929. In the 1950s, Sandage found lower values for the Hubble constant — the ratio of galaxy speed to distance from Earth from which the expansion rate is derived — than other astronomers.

Sandage's measurements suggested the universe's age to be approximately 18 billion years. Currently, data suggest the universe is about 13.7 billion years old. But even at 81, Sandage is unlikely to quit the debate that has consumed his life for decades. **— ERIN DOLAN**

Blown fuse

NASA halted the Far-Ultraviolet Spectroscopic Explorer (FUSE) mission in September after the satellite's guidance-system failed.



NASA/ESA/M. SHOWALTER (SETI INSTITUTE)

ON EDGE. Hubble imaged Uranus and its rings in 2003, 2005, and 2007. Over time, the rings' angle toward Earth shifts. They appear edge-on, as in the 2007 image, every 42 years.

Uranus' changing rings

New Hubble images show that Uranus' rings have changed shape since 1986, when Voyager 2 first visited the gas giant. The Hubble Space Telescope took thousands of pictures of Uranus and its ring system.

A team led by Imke de Pater of the University of California, Berkeley, pored through the images and noticed some of the rings had changed since the Voyager snapshots. For example, Uranus' inner rings are much more prominent than before. The team published its findings online August 23 in *Science Express*.

Astronomers can apply to studies of other solar systems what they learn from these observations, says team member Heidi Hammel of the Space Science Institute in Boulder, Colorado. **— L. L.**

New asteroid type found?

Asteroids 7472 Kumakiri and 10537 1991 RY_{16} may belong to a new class of asteroids. Astronomer Rene Duffard of the Instituto de Astrofisica de Andalucia in Spain reported that finding August 22 at the European Planetary Science Congress in Potsdam, Germany.

Spectral analysis of light reflecting off the asteroids suggests they contain basalt, a rock type "very unusual for this part of the asteroid belt," Duffard says.

The basalt indicates the asteroids were once part of larger solar system bodies. Basalt forms only if the source material melts and then resolidifies. V-type basalt asteroids, for example, are fragments of the large asteroid Vesta.

Duffard's space rocks are not V-types. Their spectra suggest a unique mineral composition, distinct from basalt asteroids previously observed.

One explanation is past collisions altered the asteroids chemically. Alternatively, the asteroids may be unique solar system bodies requiring a new category altogether. **— L. L.**

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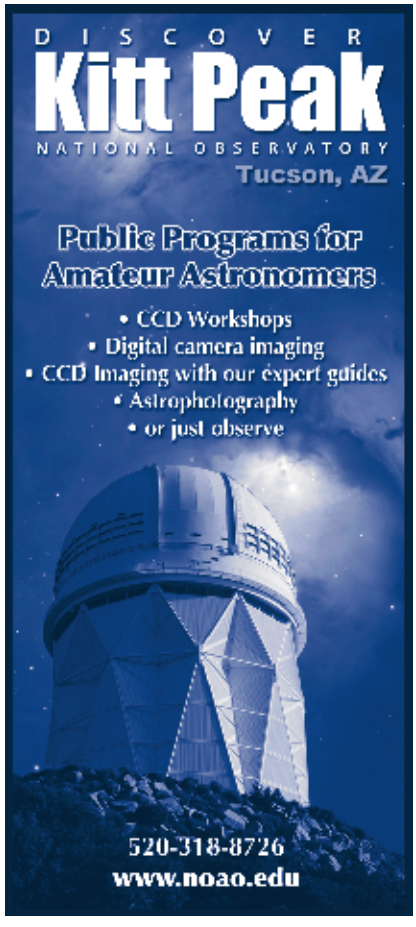

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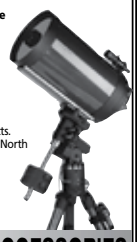

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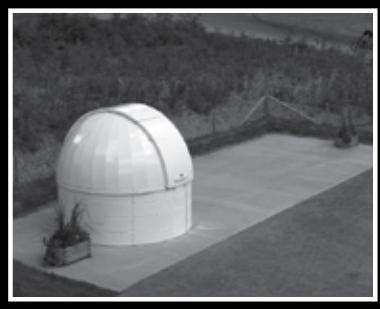

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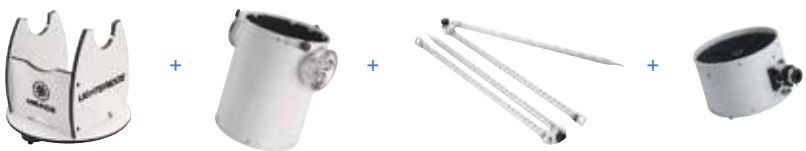

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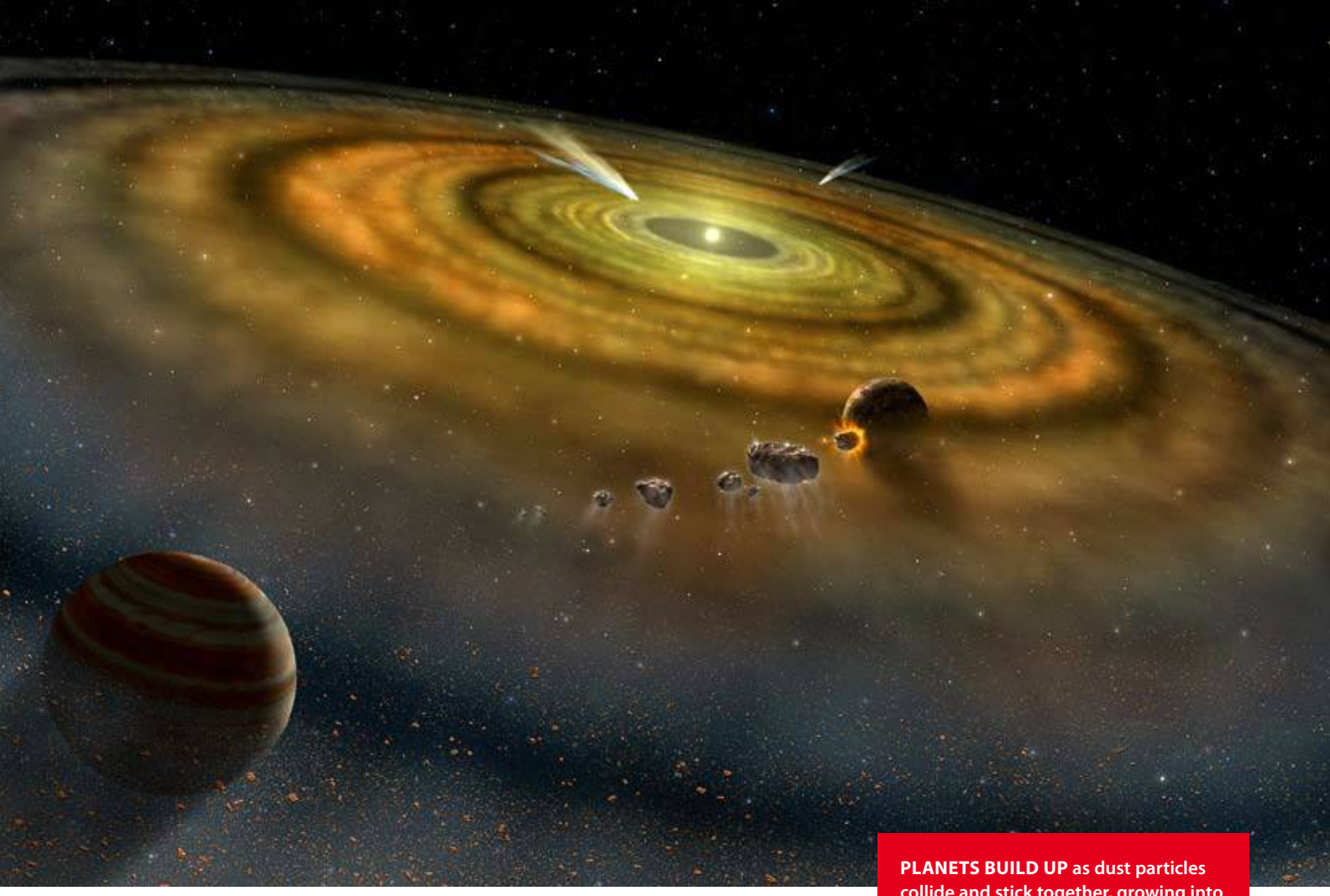
Earth's fiery start

The verdant hills, lush valleys, and blue waters that distinguish our planet today weren't there from the beginning. Peering into Earth's genesis, scientists find a world forged in fire and sculpted by ice. /// **BY JAMES TREFIL**

SOLAR SYSTEMS FORM when gravity collapses giant interstellar clouds of gas and dust. A region like the Orion Nebula (M42) will give birth to thousands of stars over its life. NASA/JPL-CALTECH/T. MEGEATH (UNIVERSITY OF TOLEDO) AND M. ROBBERTO (STScI); EARTH IMAGE ABOVE: NASA



PLANETS BUILD UP as dust particles collide and stick together, growing into ever larger rocky objects in a disk surrounding their fledgling star. Our solar system formed this way just over 4.5 billion years ago. NASA/FUSE/LYNETTE COOK

Earth hasn't always been a green and pleasant place. In fact, our planet's infancy was a violent, chaotic time. When you visualize the hellish conditions back then, it's hard to reconcile it with the lush planet we see now.

There were times, for example, when Earth was covered with a miles-thick layer of red-hot rock — what geologists call a "magma ocean." There were times when the atmosphere was so hot it could have melted steel at the surface and, paradoxically, when it got so cold the planet froze over. Through it all, a rain of gigantic meteoroids fell from the skies.

Conditions were so different back then that geologists refer to the first several hundred million years as the "Hadean" period, to conjure up ancient visions of hell. In the words of University of Maryland geologist Roberta Rudnick, "The name is classical, but the image is biblical."

James Trefil *is the Clarence J. Robinson professor of physics at George Mason University and a frequent contributor to* Astronomy.

Despite the violence of those times, recent revelations of how radioactive atoms behave allow us to paint a more complete picture of Earth's first 50 million years.

One question we can ask right at the start is: How can scientists know anything about events that happened so long ago? After all, the action of plate tectonics constantly churns Earth's surface.

The oldest surface rocks we know of, which are "only" 3.8 billion years old, come from the Isua formation in southwestern Greenland. Recently, scientists discovered a handful of individual zircon grains as old as 4.4 billion years incorporated into 3-billion-year-old rocks in Western Australia. These grains remain the only material we have that dates from Earth's formation. Thus, much of our knowledge depends on computer modeling and new techniques that involve radioactive decay.

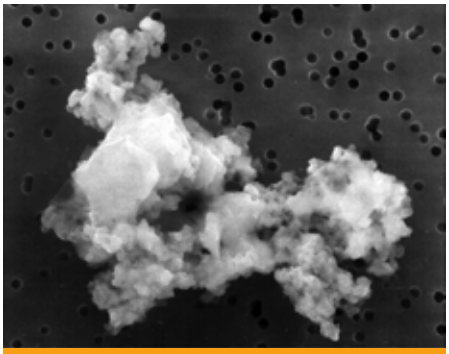
Making a solar system

French physicist Pierre Simon Laplace (1749–1827) proposed the first quantitative hypothesis of how planets like Earth form. His theory, with various additions, survives today. Basically, the solar system started with the collapse of a cloud of interstellar gas and dust — the same process we still see going on across our galaxy.

Gravity caused the cloud to fragment and condense into giant balls of heated gas that eventually became stars. Meanwhile, whirling disks around those nascent stars gave birth to the planets.

About four-and-a-half billion years ago — 4.5672 billion years, to be more precise — bits of dust around the growing Sun started sticking together to form small, inch-long clumps. Scientists have succeeded in producing these kinds of fluffy conglomerates in laboratories, so we have a pretty good idea of what went on. Our best models tell us this preliminary step occurred in about 10,000 years — a mere blink of an eye, astronomically speaking.

Astronomers do not understand as well the next step — the amalgamation of the



PRIMORDIAL DUST likely left over from the solar system's birth consists of fluffy conglomerates that stuck together. This piece was captured by a NASA U-2 high-altitude jet in Earth's stratosphere. NASA

small bits into mile-wide objects called planetesimals. However, computer models indicate this process, too, took only a few tens of thousands of years.

Once the planetesimals formed, ordinary gravitational amalgamation would have turned them into thousand-mile-wide objects called planetary embryos. Again, computer models tell us this was a fast process, involving no more than a few hundred thousand years.

Then began an amazing series of events, a kind of planetary billiards game in which gravitational forces caused these embryos to collide, break up, come together, and, in some cases, get kicked out of the solar system. Gradually, some of the heavier objects — those that became the inner planets — began to acquire most of their current mass from smaller objects they absorbed.

Although much of this planetary accretion was over by the time the solar system was just 10 million years old, it tailed off for a period thereafter. It really isn't over yet. Every time you see a "shooting star," that's a bit of primordial solar system material burning up in Earth's atmosphere. Even now, this process adds as much as 22 million pounds (10 million kilograms) to Earth's mass yearly.

During the early accretion period, Earth would have experienced a continuous rain of meteoroids. Many geologists think the energy released by this deluge heated the planet to the melting point, forming a global magma ocean. At the same time, heavy metals (mainly iron and nickel) melted and sank to Earth's center, forming its core.

Scientists have developed a number of theories to explain the core-formation process. The most picturesque has the liquid iron falling like rain through the molten rock, increasing the core's mass with each drop. Other theories envision various ways Earth's core could have coalesced from the cores of colliding planetesimals.

Whichever theory turns out to be right, however, one thing is clear: The main part of the core formed some 15 to 30 million years into Earth's lifetime. This time frame comes from our growing knowledge of the properties of radioactive isotopes (see "How scientists date radioactive isotopes" on page 36). Having a number this precise proves invaluable to theorists because it allows them to rule out any process of core formation that takes longer than a few tens of millions of years.

It's amazing how precisely scientists can date events in Earth's early history. One paper, for example, concerned a debate between two different research groups on whether Earth's correct age is 4.5672 or 4.5695 billion years.

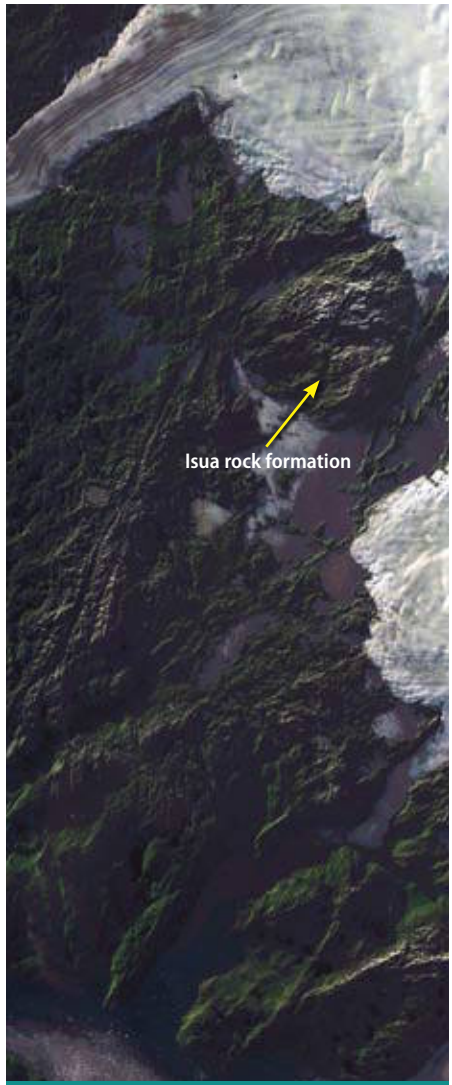
Hell on Earth

Toward the end of this period of formation and accumulation, some 40 to 50 million years after the beginning, a cataclysmic event took place. A planetary embryo about the current size of Mars plowed into Earth, striking our planet slightly off center and, in the process, spewing all sorts of rocky debris into orbit.

When this debris coalesced, it formed the Moon. The idea that the Moon arose from a collision near the end of the planetary-billiards game explains why our planet is the only one with a moon comparable in size to its parent body.

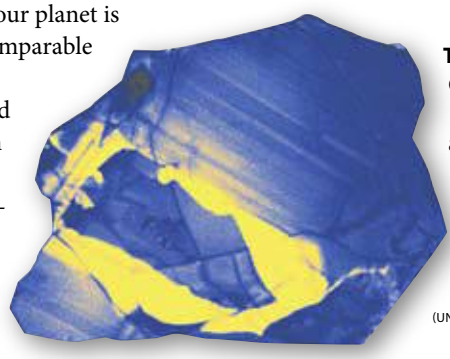
This mega-collision would have produced a truly hellish state on Earth. According to computer models, the atmosphere (at least, what wasn't blown off by the collision) would have been at the unimaginable temperature of about 4,000° Fahrenheit (2,500 K) — hotter than the melting point of iron — and topped with a cloud layer of vaporized rock. For 1,000 years, our planet would have looked like a glowing, red-hot ball. As the atmosphere cooled, the vaporized material would have rained down, accumulating at the rate of about 3 feet (1 meter) each day and forming a second magma ocean on the surface.

As Earth cooled off, the atmosphere began to look more familiar, with gases like hydrogen, carbon dioxide, nitrogen, and water vapor making up the bulk. Scientists still debate how much of Earth's original



JACQUES DESCLOITRES/MODIS LAND RAPID RESPONSE TEAM/NASA/GSFC

THE ISUA ROCK FORMATION in southwestern Greenland dates from about 3.8 billion years ago, making it the oldest surface material known on Earth.



THIS ZIRCON CRYSTAL formed 4.4 billion years ago. Scientists dug up this 200-micrometer-wide zircon in Western Australia. JOHN W. VALLEY (UNIVERSITY OF WISCONSIN)

HOW SCIENTISTS DATE RADIOACTIVE ISOTOPES

The most important tool geologists have for tracing Earth's early history involves radioactive isotopes of common materials. Two nuclei are considered isotopes of each other if they have the same number of protons but a different number of neutrons. Two isotopes of the same element, in other words, have the same chemical properties but different weights.

When a nucleus undergoes radioactive decay, the number of protons — and hence its chemical identity — typically changes. This means the daughter nucleus will have different chemical properties than the original, which turns out to be the key to the technique geologists use. Let me illustrate with a simple example: the question of when the iron in Earth sank into the interior and formed the planet's current core.

Geologists deduced the timing by examining the isotope hafnium-182 (72 protons and 110 neutrons), which decays into the more familiar metal tungsten-182 (74 protons and 108 neutrons) with a half life of about 9 million years. When Earth formed, it contained a certain amount of hafnium-182 we can determine by studying meteorites, which preserve the solar system's original composition. As time went by, this initial store gradually turned into tungsten-182, which is stable and does not undergo further transformation. Tungsten has a tendency to attach itself to metals like iron, while hafnium tends to remain in minerals and rocks.

Now imagine two scenarios: First, suppose Earth's core formed rapidly. In this case, little of the initial hafnium would have decayed before the iron sank into the interior. Instead, it would have stayed in rocks at the surface, and today we would see plenty of tungsten-182 produced by its subsequent decay.

Alternatively, imagine the core formed slowly, after most hafnium had decayed. In this case, the tungsten would have locked on to the iron as it sank, leaving a tungsten deficit at the surface today. By measuring the amount of tungsten-182 in current surface rocks, we can tell Earth's core formed almost 4.5 billion years ago.

Other radioactive processes serve the same function as the hafnium-tungsten decay, and can be used to verify the results. Scientists also can date the core's formation using the decay of manganese into chromium or the decay of palladium into silver. Similarly, scientists use the decay of iodine into xenon to date the formation of Earth's atmosphere. — *J. T.*

atmosphere survived the Moon-forming impact. It seems any gases on the side of the planet struck by the impactor would have been lost, so the debate concentrates on the fate of the gases on the shielded side.

Whatever happened to the original atmosphere, several aspects of the post-impact atmosphere loomed large for the planet's future. One is that the atmospheric pressure then would have been at least 100 times higher than it is today. The second is that the amount of carbon dioxide left behind was at least 1,000 times more than what's in the air we breathe. Finally, during the Hadean period, most water was dissolved in the magma, only to come out later when Earth cooled.

A faint, young Sun

At this point, we have to bring one more player into the story. While Earth was accumulating mass and the Moon was forming, the Sun was entering what astronomers call the main sequence — a state in which the fusion fires in its core ignited and began burning hydrogen into helium.

The Sun has been on the main sequence ever since, and it should remain there for another 5 to 6 billion years. Theories of stellar evolution tell us, however, that the Sun was only about 70 percent as bright then as it is now. Earth would have received

A MAMMOTH COLLISION between Earth and a Mars-sized object 4.5 billion years ago threw out massive quantities of material, which eventually cooled and coalesced into the Moon. FAHAD SULEHRIA

considerably less energy in the form of sunlight during the Hadean period.

Earth, then, was cooling off by radiating energy into space at the same time energy was being pumped in from two sources: the faint, young Sun and geothermal heat from the magma ocean. All this happened while a dense, carbon-dioxide-rich atmosphere produced a huge greenhouse effect.

Our best models tell us a runaway greenhouse effect dominated Earth's surface and atmosphere for the 2 million years after the collision. This stage lasted until normal chemical processes could pull the carbon out of the atmosphere, incorporate it into surface minerals, and pull it down into the planet's mantle. This was the beginning of a geological cycle — the "other" carbon cycle — that still operates today.

Because of the high atmospheric pressure, water could remain in liquid form at much higher temperatures than we are used to. Calculations suggest, for example, that as the massive greenhouse effect began to abate, water that had been incorporated in rocks came out (the technical term is "degassed") and formed a liquid ocean, even though the temperature was about 400° F (500 K) — well above water's boiling point at today's atmospheric pressure.

Blasting away

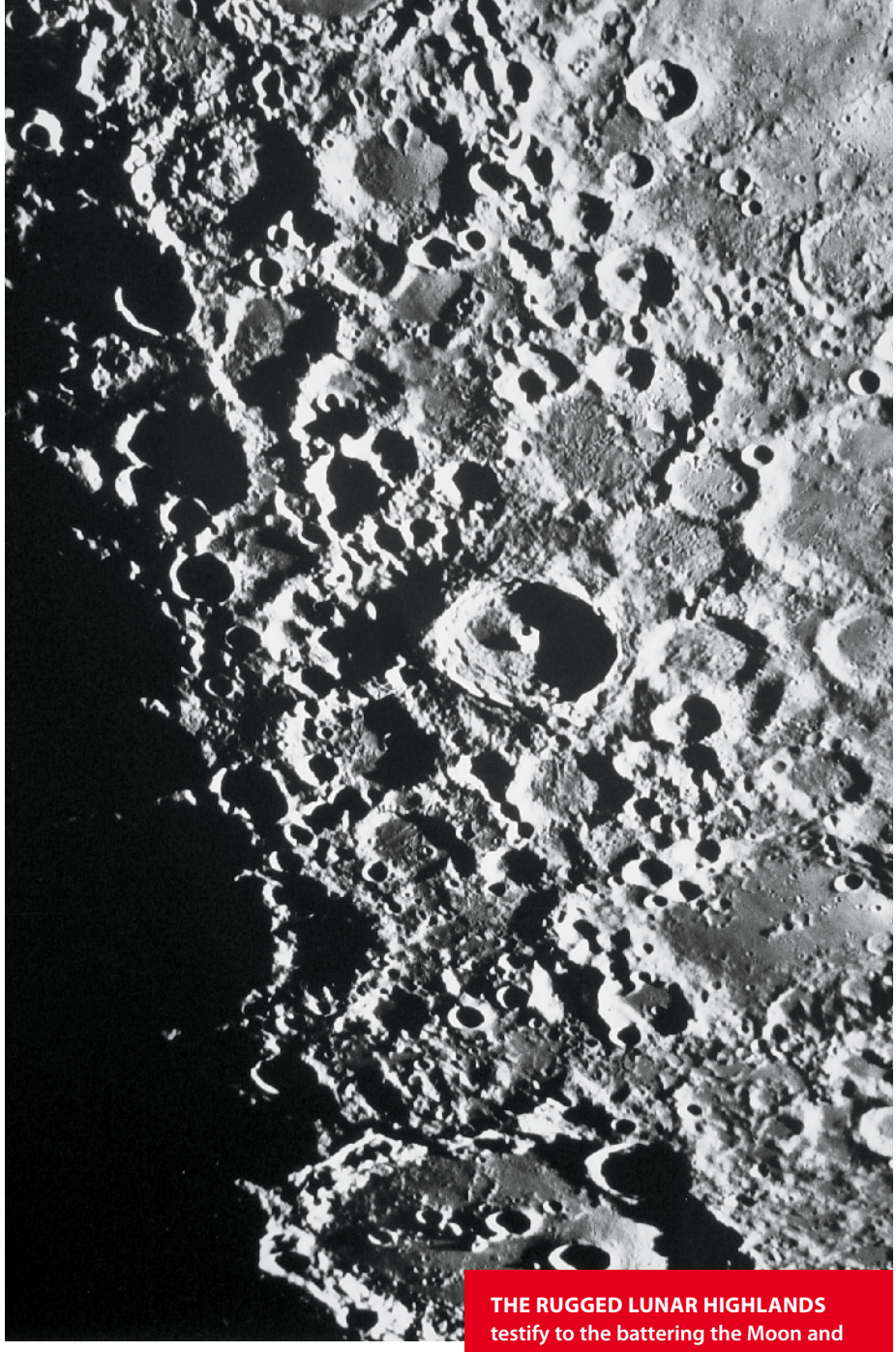
As normal chemical processes removed carbon dioxide from the atmosphere, the greenhouse effect began to lose its power to keep our planet warm. Furthermore, except during brief periods immediately following major impacts, the geothermal heat generated by the cooling planet would have been small as well.

Given the faintness of the early Sun, there wouldn't have been enough energy to keep the planet's temperature above the freezing point, and Earth would have been jerked from its fiery beginning into a wintry snowball. The liquid water on its surface would have frozen, and, from space, it would have looked like a shiny sphere of ice — perhaps not too different from Jupiter's moon Europa. Scientists continue to debate how thick this ice layer would have been, but some researchers suggest it could have been up to a few hundred feet (100 meters) thick. At least at this time, we can say that hell did freeze over.

As the Sun warmed and Earth began to approach a steady state, our planet experienced one more period of intense impacts, called the late heavy bombardment, around 3.9 billion years ago. Evidence for this comes primarily from examining craters on the Moon, and arguing that whatever happened to our lunar cousin must have happened even more frequently on Earth. After all, Earth is a bigger target and has stronger gravity to pull in rogue objects.

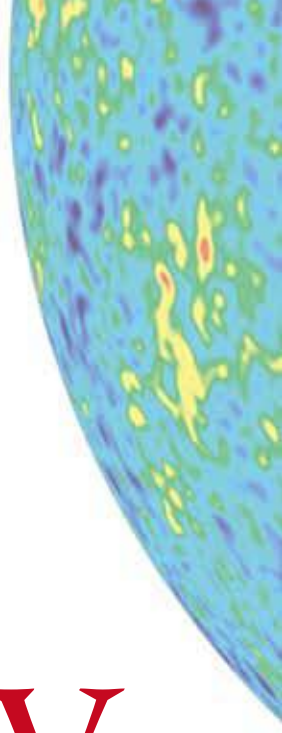
The impact of an asteroid the size of Arizona — and several this big reside in the current asteroid belt — would have brought in enough energy to boil the oceans and turn the atmosphere to steam for a thousand years. Smaller but still substantial impacts would have boiled off the ocean's upper layer. Thus, if life had started to develop by this early time, only organisms deep underground or at deep ocean vents would have had a chance to survive. This seems to agree with the theory that modern life descended from thermophilic (heat-loving) organisms.

In any case, once all this turmoil ceased, in the words of NASA scientist Kevin Zahnle, "Earth's youthful excesses were mostly soon forgotten." When the Hadean period ended, Earth settled down into a comfortable middle age — an age that allowed intelligence to evolve and ponder our planet's tumultuous beginnings.



THE RUGGED LUNAR HIGHLANDS testify to the battering the Moon and Earth experienced during the "late heavy bombardment" some 3.9 billion years ago. *CONSOLIDATED LUNAR ATLAS* (UA/LPI)

Why is the solar system cosmically aligned?



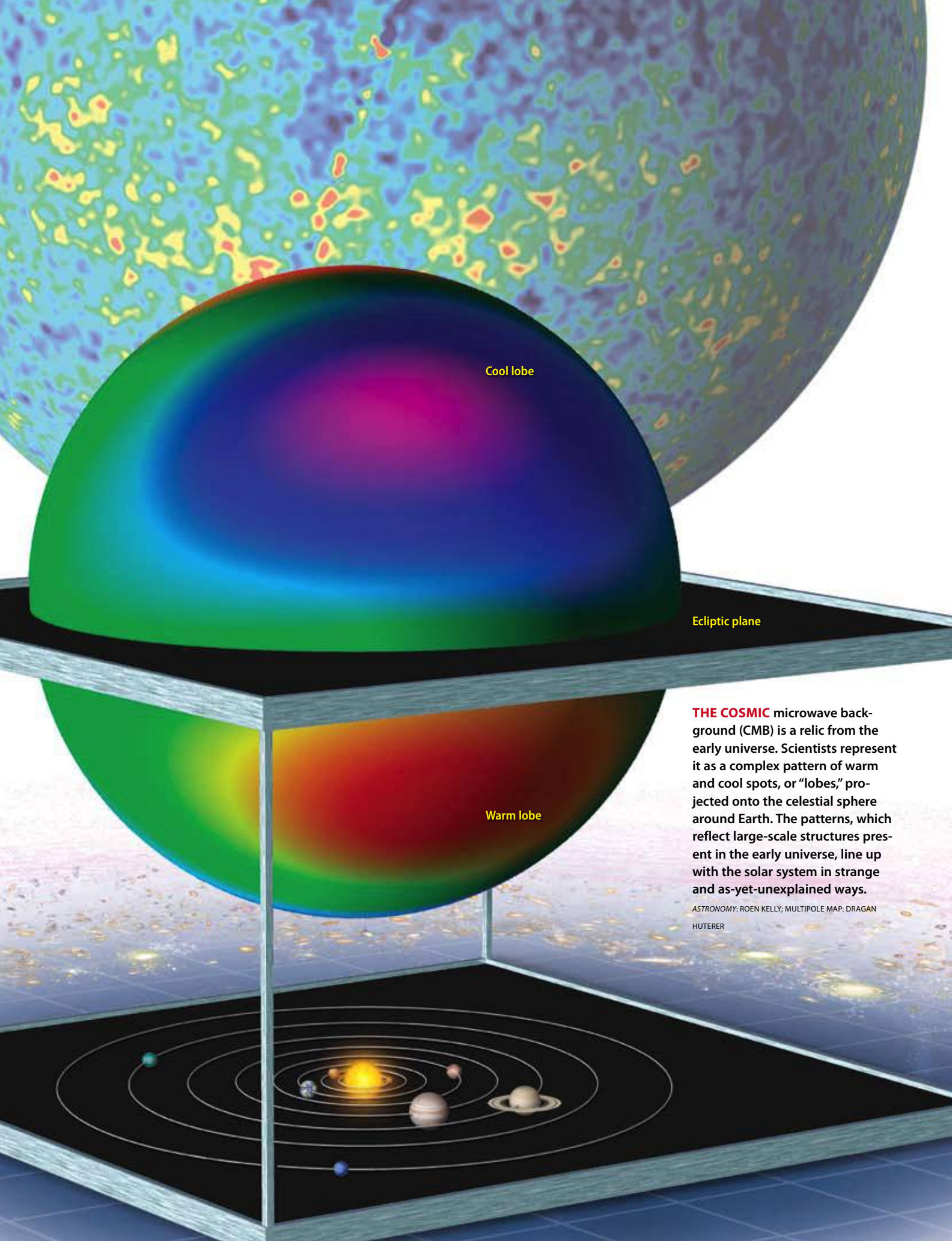
The solar system seems to line up with the largest cosmic features. Is this mere coincidence or a signpost to deeper insights?

/// BY DRAGAN HUTERER

Imagine visiting a Museum of Cosmology, where the signature display is a giant case that contains a realistic model of the observable universe. Herein lie all the stars and galaxies we can see from Earth — the parts of the universe from which light has had enough time to reach us in the 13.7 billion years since the Big Bang. The museum curators have done an excellent job, and the model is complete with planets, stars, and galaxies.

As you stand in front of the display and squint, you can barely discern the smallest-scale features: billions of individual stars, many with planets and moons. As you step a good distance away from the display to get a better perspective, you notice the larger structures: star clusters and galaxies, each containing a sea of suns. Stepping back farther, you start to discern a web of filaments in the vastness, and notice that clusters of galaxies lie at the intersections of the largest filaments. At this distance from the display, you can see patterns that extend 45 billion light-years, all the way out to the edge of the observable universe.

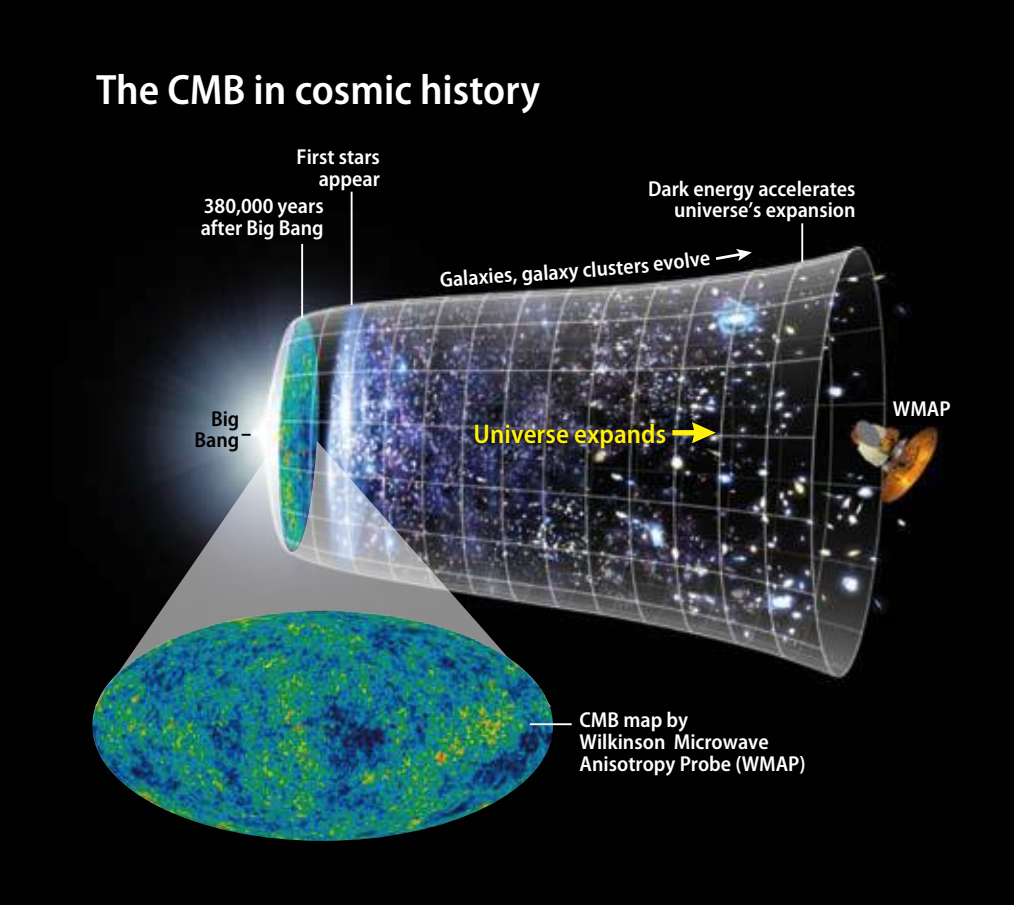
Intrigued by this zoo of structures on different scales, you walk over to the opposite end of the huge Main Hall to get a sense of the big picture. And you are



THE COSMIC microwave background (CMB) is a relic from the early universe. Scientists represent it as a complex pattern of warm and cool spots, or "lobes," projected onto the celestial sphere around Earth. The patterns, which reflect large-scale structures present in the early universe, line up with the solar system in strange and as-yet-unexplained ways.

ASTRONOMY: ROEN KELLY; MULTIPOLE MAP: DRAGAN HUTERER

The CMB in cosmic history



IN THE FIRST moments after the Big Bang, the universe underwent a period of rapid expansion. About 380,000 years later, the universe expanded enough to become transparent to radiation. From that time forward, particles of light (photons) traveled freely throughout the cosmos. The cosmic microwave background (CMB) is a record of the universe's state at that moment. As the universe expanded, stars and galaxies evolved. Later, large-scale structures such as galaxy clusters emerged. The Wilkinson Microwave Anisotropy Probe (WMAP) mapped the cosmic microwave background. NASA/WMAP SCIENCE TEAM

shocked to see vast patterns within all those stars and galaxies that seem to line up with the direction of the Sun's motion through the universe. Even stranger, some aspects of the cosmic geometry seem more flattened than spherical, and line up nearly perpendicular to the plane along which the planets race around the Sun.

In reality, you would need a very special kind of vision to see the alignments cosmologists have begun to find in the geometry of the universe. Seeing them requires sophisticated mathematical analysis that enables us to explore the finest details of how the universe is put together.

Careful analyses have confirmed these alignments exist. But we don't know whether they are bizarre coincidences or if something more fundamental is at work.

The origins of the universe's structure lie in the first moments after the Big Bang. But how could the early universe possibly have "known" about the solar system's geometry when it developed 4.5 billion years ago? Could such a bizarre alignment have arisen in the early universe, or is the answer in the solar system itself — some as-yet-unknown factor that skews our observations?

The quest for an answer has whetted the appetites of cosmologists to understand the structure of the universe on its largest scales. Moreover, solving the mystery of cosmic alignments may ultimately require us to revise some bedrock assumptions of modern cosmology and what happened in the first moments after the Big Bang.

Dragan Huterer *is a theoretical cosmologist and a professor in the department of physics at the University of Michigan in Ann Arbor.*

A look in the microwave

With modern telescopes and sensitive instruments, we can observe distant galaxies and clusters of galaxies, and accurately map their distribution. Unfortunately, it's not possible to "zoom out" from our present moment in time and space to observe the entire universe. Moreover, even with a perfect telescope and nothing blocking our view, we could only see galaxies that are no farther than 45 billion light-years from us. Light from the more distant objects simply has not had time to reach us yet.

To map the universe's structure we would need something like a fossil record preserving information about conditions in the early universe, when the seeds were planted that grew into structures we observe 13.7 billion years later.

Fortunately, we have such a fossil. It's called the cosmic microwave background (CMB). Arno Penzias and Robert Wilson of Bell Laboratories discovered it in 1965.

In the early universe, photons (particles of light with zero mass) and protons and electrons (particles found in atoms) swarmed in a dense mass, like a vast number of bees trapped in a box. Around 380,000 years after the Big Bang, however, an important transition occurred: The expanding universe became transparent to radiation, and the photons were free to travel. Today we observe the CMB as a fog of microwave photons coming at us from all directions, filling the entire universe.

Cosmic snapshot

The CMB is a snapshot of the early universe. After the Big Bang, gravity drew the densest regions together. These concentrations of matter evolved over eons of time into galaxies, galaxy clusters, and all the other cosmic structures we observe today.

The less-dense, rarefied regions evolved into vast expanses of cosmic emptiness, filling the space between galaxies. You can see the results of gravitational collapse in the night sky as a seemingly random pattern of stars and galaxies.

The CMB's temperature is nearly uniform across the sky, measuring just 2.73 Kelvin, or 2.73° Celsius above absolute zero. But the CMB is not completely uniform; it contains many small patches where the background temperature is warmer or cooler, varying slightly above and below 2.73 K. These variations in the sea of radiation are small, about one part in 100,000, or equivalent to the roughness of dust on a billiard ball's surface.

The CMB's rough spots, called anisotropies, reflect inhomogeneity in the early universe — ripples, if you will, on the surface of the vast photon sea that existed after the Big Bang. Unlike stars, anisotropies in the CMB are extremely faint, invisible to the naked eye and even to most telescopes.

In 1992, the Cosmic Background Explorer (COBE) satellite famously mapped the anisotropies for the first time. Seeing COBE's map of the CMB, cosmologist Stephen Hawking proclaimed it "the discovery of the millennium, if not all time," precisely because COBE had detected the seeds of all cosmic structure today.

Later, scientists mapped out the CMB at much higher resolution with another space telescope, the Wilkinson Microwave Anisotropy Probe (WMAP). Its remarkable findings — first published in 2003 and still continually refined as WMAP continues its observations — have revolutionized our understanding of the universe.

Within each square degree of sky, WMAP revealed many finer variations in the CMB's temperature. It was like switching from a handheld magnifying glass to a microscope. Cosmologists use WMAP data to measure the distribution of anisotropies and compare it to what current theories predict. WMAP's observations also enable astronomers to more accurately measure the abundance of dark matter, the stuff in and around galaxies that we can't see with conventional telescopes but still has gravity.

Finally, with WMAP we can also study dark energy, the mysterious component causing the universe to expand at an ever-faster rate.

CALTECH

UPON SEEING anisotropies in the cosmic microwave background revealed by COBE, cosmologist Stephen Hawking proclaimed it "the discovery of the millennium, if not all time."

The cosmic orchestra

Just looking at the WMAP picture of the universe reveals only so much information. More valuable insights await discovery in the underlying patterns of warm and cool spots in the microwave map. Mathematics allows us to break down the speckles into more fundamental patterns and probe the underlying processes that produced the CMB's complexity. We do this by describing the pattern of warm and cool spots in terms of mathematical functions called multipoles.

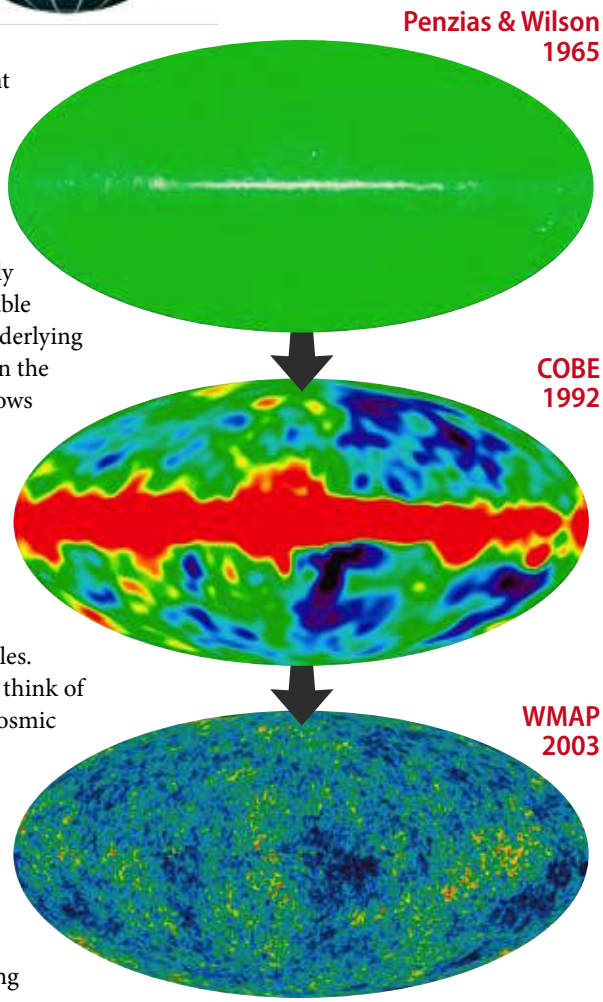
To understand the multipoles, think of the microwave background as a cosmic orchestra with a large number of instruments, each playing a simple musical part. The simultaneous performance of all these individual parts adds up to a symphony. But what if you wanted to focus on a particular portion of the whole, like the string section, or even a single violin?

For analyzing music, you would perform a Fourier analysis. When a violinist bows a string to make a high C note, the sound actually contains many individual subcomponents called harmonics. Each harmonic is a pure, wavering tone — like that of a tuning fork. Hypothetically, you could use a computer to synthesize a large number of harmonics, add them back together, and reproduce a sound similar to that of the bowed violin string.

You could also perform a Fourier analysis of the whole orchestra. It, too, can be represented as a sum of a large number of pure harmonics. A computer synthesizer could easily reproduce a symphony or an opera as a complicated sum of many

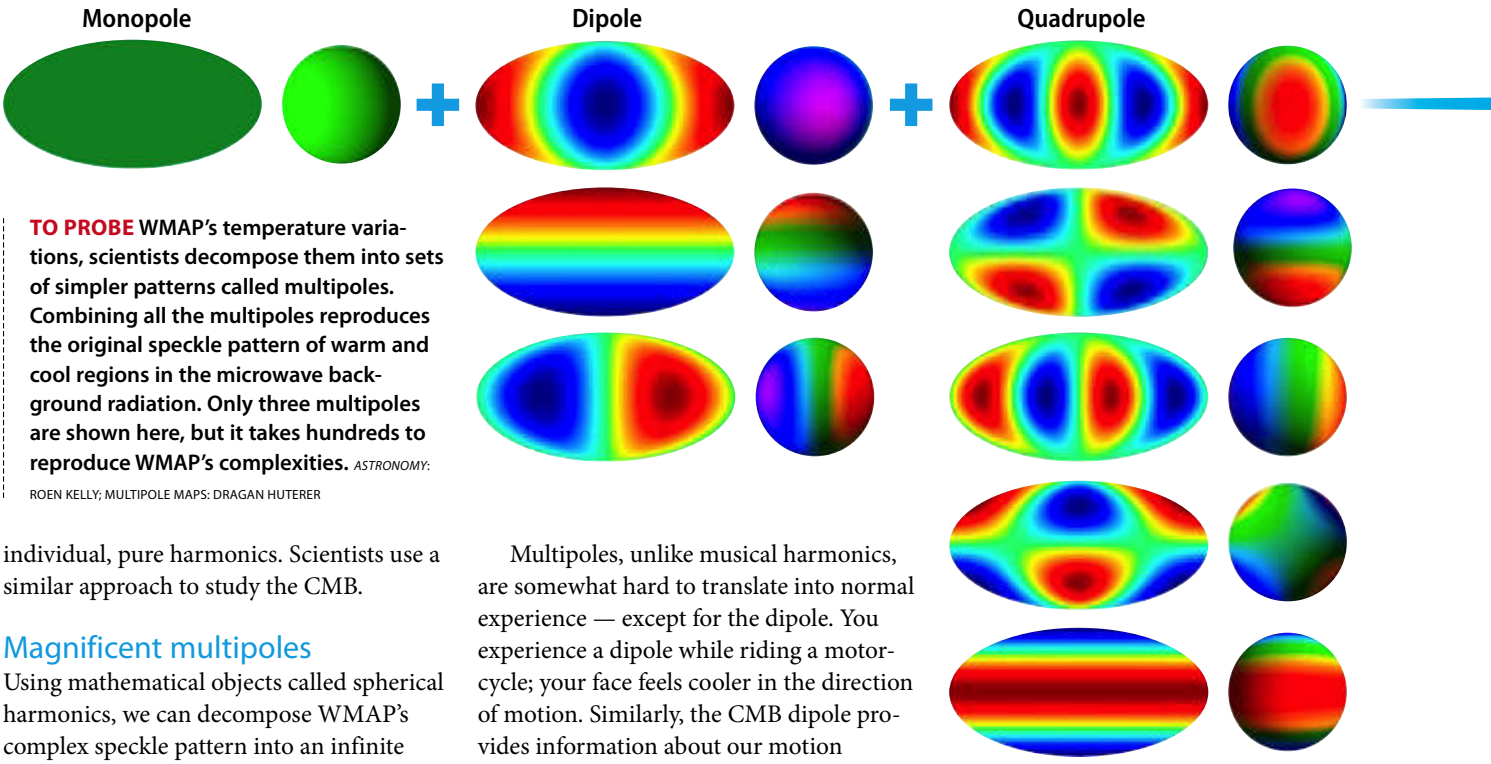
Mapping the CMB: our evolving view

The CMB mapped onto the celestial sphere.



WE OBSERVE the CMB on the sky, so it can be mapped onto a sphere. But to make the entire CMB visible on the page, scientists map it onto an oval. Upon its discovery in 1965 by Arno Penzias and Robert Wilson, the CMB's temperature appeared largely uniform. With the launch of the COBE satellite, followed by WMAP, a far more detailed picture of the CMB has emerged. *ASTRONOMY*: ROEN KELLY; CMB MAPS: NASA/WMAP SCIENCE TEAM

From multipoles to WMAP



TO PROBE WMAP's temperature variations, scientists decompose them into sets of simpler patterns called multipoles. Combining all the multipoles reproduces the original speckle pattern of warm and cool regions in the microwave background radiation. Only three multipoles are shown here, but it takes hundreds to reproduce WMAP's complexities. *ASTRONOMY:* ROEN KELLY; MULTIPOLE MAPS: DRAGAN HUTERER

individual, pure harmonics. Scientists use a similar approach to study the CMB.

Magnificent multipoles

Using mathematical objects called spherical harmonics, we can decompose WMAP's complex speckle pattern into an infinite series of warm and cool regions, or lobes, arranged in increasingly complex patterns on a sphere. These basic patterns are called multipoles. They have taught us a lot.

The simplest multipole in the CMB is called the monopole. It corresponds to the CMB's average temperature, 2.73 K.

The next-highest multipole is the dipole. It tells us the overall direction in which the CMB is cooler or warmer, and by how much. The dipole is described by three different modes. In each mode, the CMB temperature is warmer in one hemisphere and cooler in the opposite hemisphere.

Next comes the quadrupole (5 modes) and the octopole (7 modes). Each higher multipole has modes with more complex combinations of warm and cool lobes. Each multipole is associated with a number specifying its overall contribution to the whole.

In principle, an infinite number of multipoles are needed to describe a temperature map. However, because all maps based on actual observations and measurements have a finite resolution, a limited number of multipoles can fully describe a map.

For example, COBE's map of the CMB has an angular resolution of 7° and requires about 20 multipoles to describe it. In contrast, WMAP's observations have a resolution of about ¼ of a degree and require several hundred multipoles to create a full description of its complexities.

Multipoles, unlike musical harmonics, are somewhat hard to translate into normal experience — except for the dipole. You experience a dipole while riding a motorcycle; your face feels cooler in the direction of motion. Similarly, the CMB dipole provides information about our motion through space: Much like the motorcyclist, the orientation of the warm and cool lobes of the dipole tells us the solar system's direction of motion through the CMB.

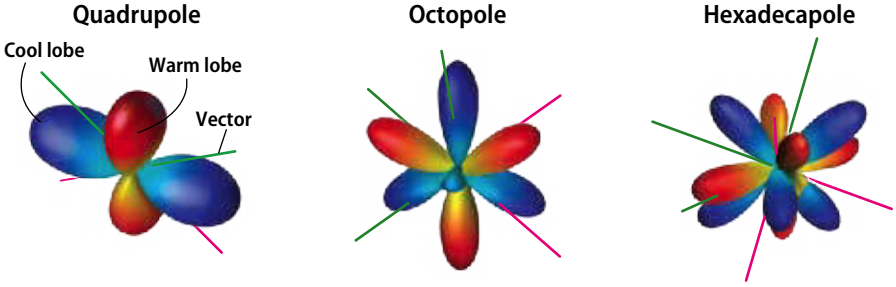
The orientation of the multipoles is important, because they describe a pattern of temperature variations on the observable universe all around us. So imagine yourself looking out on the sky; you are surrounded by a spherical surface painted with the cosmic microwave background as measured by COBE and WMAP. The pattern can be recreated by combining the hot-and-cool patterns on a series of multipoles arranged the right way in relation to each other.

Strange alignments

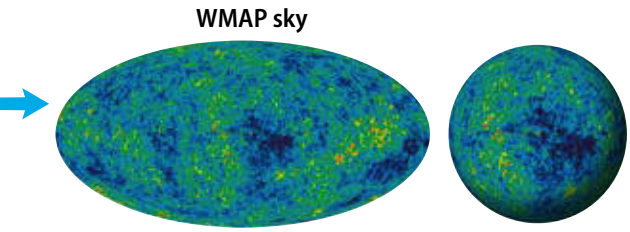
Soon after WMAP returned its first data, researchers began to see odd features of the CMB multipoles. For example, Max Tegmark and Angelica de Oliveira-Costa of the Massachusetts Institute of Technology and Andrew Hamilton from the University of Colorado looked at individual multipoles of CMB anisotropies at large scales.

Tegmark and de Oliveira-Costa found the warm and cool lobes of the octopole lie in a single plane. Furthermore, the quadrupole lies nearly in the same plane. This

What are multipole vectors?



THE TEARDROP-SHAPED lobes in these figures, called multipole vectors, represent large-scale patterns in the CMB temperature. The vectors (little "sticks" sprouting between the lobes) encode information about how the warm and cool lobes are oriented in space and to each other. Studies employing multipole vectors have revealed the various ways our solar system is parallel or perpendicular to large-scale temperature patterns in the CMB and, therefore, to the biggest structures in the universe. DRAGAN HUTERER/CRAIG COPI



could happen by chance only about 0.1 percent of the time.

Around the same time, I and two other physicists at Case Western Reserve University, Craig Copi and Glenn D. Starkman, developed a novel method to represent CMB temperature anisotropies. Our new method reduced the warm and cool lobes in the multipoles to a set of "sticks" with directions encoding the lobes' physical orientation in space.

Multipole vectors naturally define directions and planes, making it easier to identify alignments. Developing the multipole vectors allowed us to examine how the CMB's large-scale features align with each other and the ecliptic — the plane of Earth's orbit around the Sun. We also looked for alignments with large-scale structures such as the Local Group of nearby galaxies and the Milky Way itself.

Ecliptic oddities

Armed with multipole vectors, and joined by Dominik J. Schwarz of the European Organization for Nuclear Research (CERN), we have discovered unexpected patterns in the CMB. Not only are the quadrupole and octopole planar, but their planes are nearly perpendicular to the ecliptic. Moreover, we found that the ecliptic plane lies precisely between the warmest and coolest lobes of the combined quadrupole plus octopole map.

The likelihood of these alignments happening by chance is less than 0.1 percent. Finally, the quadrupole and octopole planes are also perpendicular with the CMB dipole, which points to the direction of motion of the solar system. Why CMB patterns are oriented to the solar system is not at all understood at this time.

Other researchers found similarly unlikely alignments. For example, Kate Land and João Magueijo of Imperial College in London found that temperature anisotropies in multipoles 4 through 7 also align with a particular axis close to the CMB dipole, and to the Sun's motion through space. They have humorously dubbed this odd alignment — apparently the same one we found — the "axis of evil."

The elusive explanation

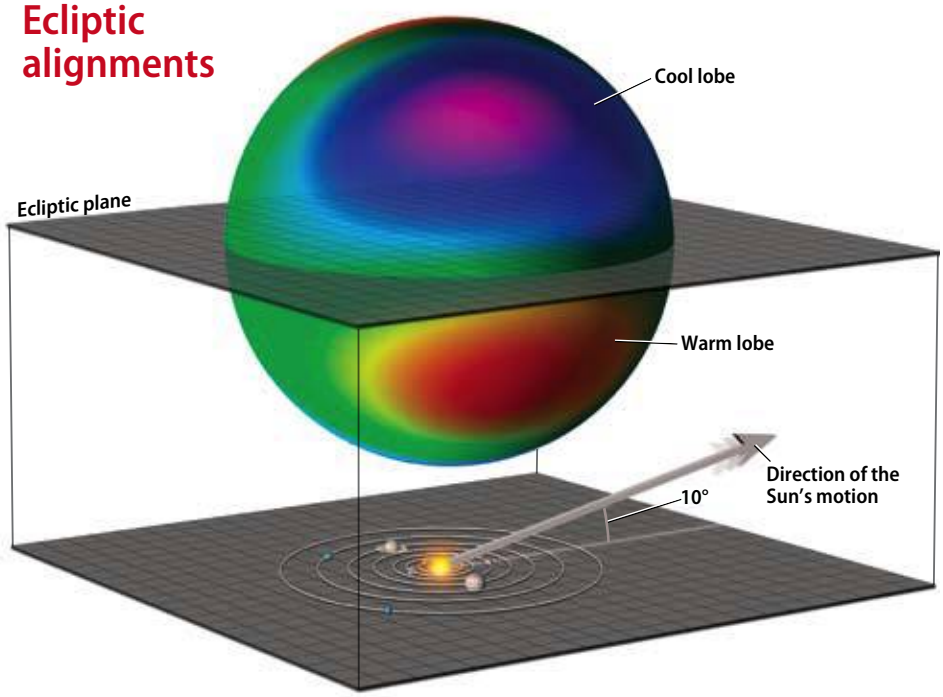
Many cosmologists find the various CMB alignments extremely unlikely to have occurred by chance. Moreover, nearly all the alignments point to the solar system's motion or the orientation of the ecliptic plane. Is there a deeper explanation?

Researchers have considered a variety of possibilities. One might be some kind of imperfection in WMAP's detector that introduces the patterns, but there's no evidence for this. It is also possible that some as-yet-undiscovered signal — a huge cloud of dust in the solar system, for example — is masquerading as a cosmological CMB. Another speculation is that a preferred direction of the CMB arose early in the universe and has persisted. In each case, the explanation either introduces more coincidences than it solves, or else is simply not consistent with our knowledge of the solar system or the universe's structure.

The search for explanations is ongoing. We also eagerly expect new data, such as additional temperature maps from WMAP. In a few years, we will also have data from the European Space Agency's Planck satellite. Like WMAP, Planck is a space telescope that scans the whole sky. But Planck's observational technique is different from that of WMAP and it will, therefore, provide a crucial complement and cross-check to WMAP's measurements. Finally, planned wide-field telescope surveys at optical wavelengths — covering large chunks of the sky and looking at nearby galaxies and others billions of light-years away — might be able to shed light on the distribution of the largest structures.

In the meantime, we can appreciate WMAP's gift to cosmology. It has provided exciting data to test theories of the universe's origin and evolution and posed new conundrums that will only deepen our appreciation for the cosmic symphony that plays in the sky.

Ecliptic alignments

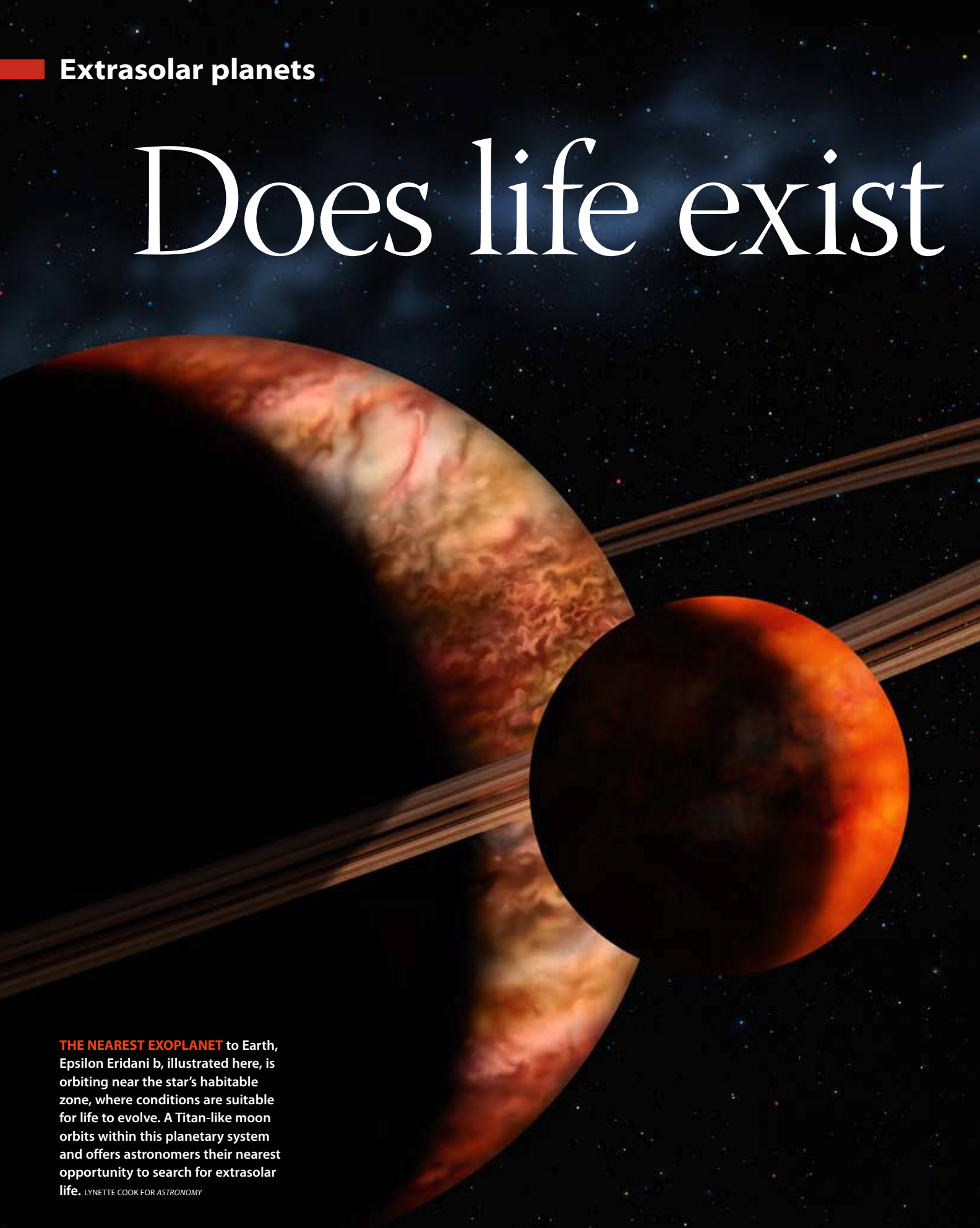


ODD ALIGNMENTS hide within the multipoles of the cosmic microwave background. In this combination of the quadrupole and octopole, a plane bisects the sphere between the largest warm and cool lobes. The ecliptic — the plane of Earth's orbit projected onto the celestial sphere — is aligned parallel to the plane between the lobes. In addition, the Sun's direction of motion through the universe is only 10° from lying in the same plane.

ASTRONOMY: ROEN KELLY; MULTIPOLE MAP: DRAGAN HUTERER

WEB EXTRA See a video about WMAP and the cosmic microwave background at www.Astronomy.com/toc.

Does life exist



THE NEAREST EXOPLANET to Earth, Epsilon Eridani b, illustrated here, is orbiting near the star's habitable zone, where conditions are suitable for life to evolve. A Titan-like moon orbits within this planetary system and offers astronomers their nearest opportunity to search for extrasolar life. LYNETTE COOK FOR *ASTRONOMY*

on this exoplanet?

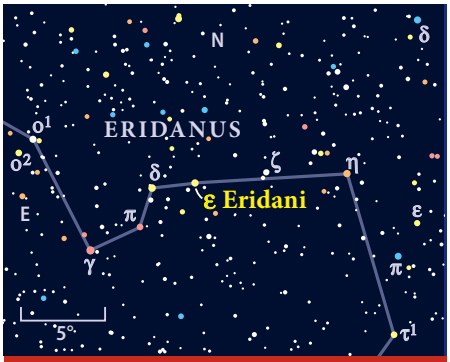
Just 10 light-years away, the Sun-like star Epsilon Eridani anchors a planetary system that may hold the seeds of life. /// **BY RAY VILLARD**

Could the embryonic stages of life be taking place a scant 10 light-years from Earth? Astronomers searching for new worlds where life can take hold find the planetary system surrounding the Sun-like star Epsilon Eridani intriguing. Possible moons around an exoplanet that swoops near the star's habitable zone makes Epsilon Eridani worth a closer look.

In 1960, American astronomer Frank Drake targeted Epsilon Eridani in a search for extraterrestrial intelligence. Drake aimed the 40-foot (12 meters) Green Bank radio telescope at the star and listened for transmissions from intelligent life dwelling on any orbiting planets.

Then, astronomers didn't know the star was only 800 million years old — too young for intelligent life to have evolved, assuming Earth's rate of biological evolution is typical. (The first primitive microorganisms likely began populating a youthful Earth when our Sun was only 800 million years old.)

It wasn't until 1998 that astronomers discovered a gas-giant planet (called Epsilon Eridani b) orbiting Epsilon Eridani. What's tantalizing is that life could be emerging right now on a young, comparatively massive, Titan-like moon orbiting Epsilon Eridani b — a possibility that intrigues modern day astrobiologists.



SUN-LIKE STAR Epsilon Eridani lies about 10.5 light-years away in the constellation Eridanus. The third-closest star to Earth viewable without a telescope, Epsilon Eridani shines at 3rd magnitude. *ASTRONOMY:* ROEN KELLY

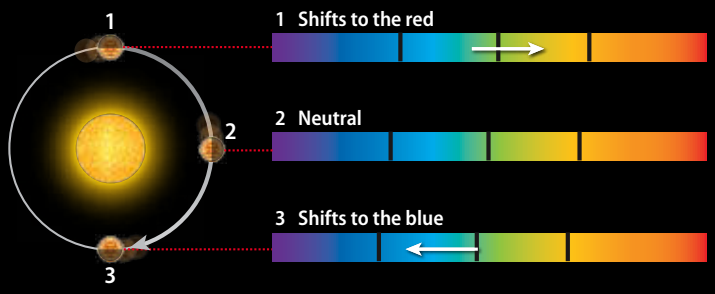
A slight wobble

Radial-velocity observations detected the star's slight wobble, which the scientists interpreted as the gravitational tug of a planet. Artie Hatzes, of Thuringia State Observatory in Germany, and co-investigators at McDonald Observatory in Texas reported finding the distant planet in 2000.

But radial-velocity measurements allow astronomers to set only a lower limit on the planet's mass. What's more, some astronomers doubted the planet existed at all. Because Epsilon Eridani is a young and active star, the suspected gravitational pull of an orbiting planet could instead be caused by gas motions on the star's surface.

More recent Hubble Space Telescope observations, made by G. Fritz Benedict and Barbara E. McArthur of McDonald Observatory, yielded a precise mass for the exoplanet. Hubble measured how the planet causes a slight displacement in the star's motion. Combined with ground-based measurements of the star's wobble, this shows the planet's orbit tilts 30° relative to Earth's. The combined Hubble and ground-based telescopic data yield a precise measurement of the planet's mass — 1.5 Jupiter-masses — and confirm the initial estimate made in 2000. Epsilon Eridani b is real,

Radial-velocity method



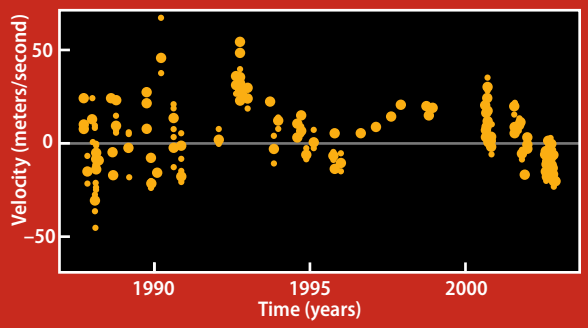
A planet's gravity tugs on its parent star, inducing a wobble in the star's motion. As the star moves closer to Earth, the star's spectral lines shift toward the blue; as the star moves away, the lines shift to the red. These changes allow astronomers to deduce a planet's minimum mass. A variation on this technique — in which a planet alters the timing of a pulsar's signal — has led to the discovery of four planets. *ASTRONOMY:* ROEN KELLY

Pros

This is now the leading method — about 90 percent of known exoplanets were found with this technique. It's great at finding heavy planets, which cause bigger changes in radial velocity.

Cons

This method yields only a minimum mass — the planet could actually be much more massive. Observations must stretch over a long period to find planets in large orbits.



DOPPLER MEASUREMENTS show Epsilon Eridani wobbles slightly. Velocity-versus-time measurements were astronomers' first indication of a planet orbiting the nearby star. *ASTRONOMY:* ROEN KELLY, AFTER CALIFORNIA AND CARNEGIE PLANET SEARCH TEAM

and it's too small and lightweight to be a brown dwarf. These contain at least 12 Jupiter-masses.

The Hubble observations reveal that planet's orbit lies in the same plane as a vast ring of dust orbiting Epsilon Eridani. This tends to confirm the idea that planets form from a disk of dust encircling a newborn star.

Abode of life?

Astronomers concluded from radial-velocity measurements that Epsilon Eridani b is a gas giant — a fact that rules it out as a place for finding life as we know it. The behemoth's atmosphere is probably a lot like Jupiter's — mostly hydrogen and helium, with trace amounts of methane, ammonia, and other gases. The planet likely has no solid surface. Astronomers suspect its deep, turbulent atmosphere has huge convection cells that alternately cook and freeze any organic material caught up in their vertical motions.

However, potentially habitable moons could very likely circle Epsilon Eridani b. In 2006, Robin Canup and William Ward of the Southwest Research Institute in Boulder, Colorado, published research that suggests satellites are common around jovian planets. Their simulation models the growth of moons that formed within disks of dust and gas produced during the final stages of a gas-giant planet's growth. The model reproduced the basic properties of Jupiter and Saturn's satellite systems.

Canup and Ward propose moons grow through a balance of two processes. First, a flow of material supplies gas and small particles to a disk orbiting the gas planet. Satellites grow inside these disks.

Next, the satellites spiral into the planet thanks to drag and gravitational interactions with the disk. In terms of the total amount of material available for making satellites, these two processes balance out. If most of the mass goes into one body, their model suggests a Mars-sized moon could form around a Jupiter-mass planet.

What's intriguing is that the two largest gas giants in the solar system host a family of chemically and geologically diverse satellites. There's Jupiter's volcanic moon Io, Europa with a likely subsurface ocean of water, and Saturn's largest moon Titan with its dense and organic-rich atmosphere.

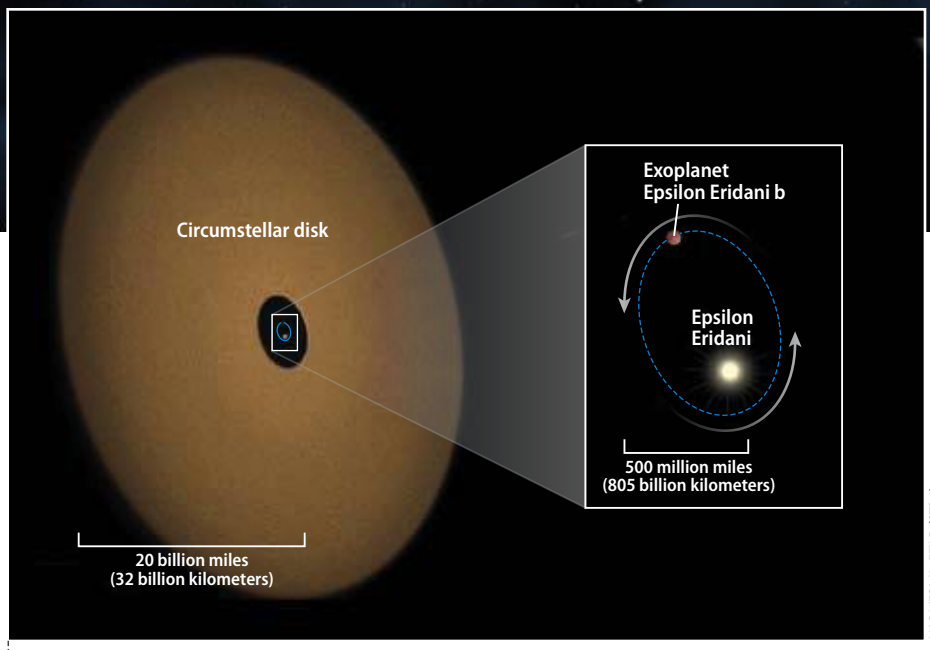
Jupiter's four Galilean satellites and Saturn's planet-sized moon Titan show great variety. But the total mass in each satellite system is similar — one-hundredth of 1 percent of its parent planet's mass.

Earthlike Titan

Titan's makeup compares to Earth's composition before life appeared nearly 4 billion years ago. Organic compounds coat Titan's surface. The moon's dense atmosphere of nitrogen and methane cloud layers resembles early Earth's primeval chemistry. Titan's hydrological cycle of liquid methane and ethane rainfall forms lakes and rivers.

Titan is a dynamic world with complex geologic processes. Its few craters indicate its surface may be relatively young due to earthlike processes of tectonics, erosion, wind, and volcanism. NASA's Cassini spacecraft photographed a 19-mile-wide (30 km) volcano. Saturn's tidal pull may power the volcano, which continuously replenishes Titan's atmosphere with methane. "Titan is 'Earth II.' Anywhere you find complexity and energy, you want to go looking for life," says planetary astronomer Keith Noll of the Space Telescope Science Institute in Baltimore.

Ray Villard *is the news director at the Space Telescope Science Institute in Baltimore. His most recent article for* Astronomy *was "Hubble discovers 16 exotic planets" in the January 2007 issue.*



NASA/ESA/A. FEILD (STScI)

JUPITER-LIKE EXOPLANET Epsilon Eridani b orbits its Sun-like star, Epsilon Eridani, every 6.9 Earth years. The Hubble Space Telescope shows the exoplanet orbits in the same plane as the star's circumstellar disk. This confirms planets form from disks around stars.

Occasional comet impacts on Titan may warm localized regions, causing brief chemical reactions that may be the precursors of life. But there's a problem. At 1 billion miles (1.6 billion km) from the Sun, Titan is a frigid place at nearly –300° Fahrenheit (–180 Celsius). So, many astronomers consider Titan a case of "arrested development," at least for life as we know it. Move Titan closer to the Sun, however, and astrobiology could explode across the great earthlike moon.

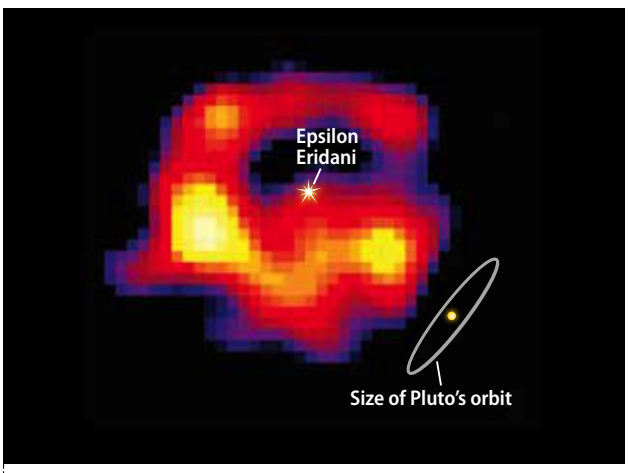
Similar processes could happen on any Titan-like world orbiting Epsilon Eridani b. Such a world would be much warmer, at least for a portion of its 7-year orbit about the star. The planet's elongated, or eccentric, orbit carries it as close to Epsilon Eridani b as Earth is from our Sun, and as far away as Jupiter.

Cold and hot

What's tantalizing is that the planet's orbit carries it close to — but not inside — Epsilon Eridani's habitable zone, the region where temperatures are warm enough for liquid water to remain on the surface of a planet with an atmosphere. Epsilon Eridani is a K-class star, slightly cooler than our Sun and one-quarter its brightness. This means the habitable zone would be smaller and narrower than our Sun's.

Because of the planet's eccentric orbit, any satellites would experience long, cold winters and brief, hot summers. As German astronomer Johannes Kepler (1571–1630) deduced 400 years ago, a planet moves fastest along its orbit when closest to the Sun and slowest when farthest away.

Still, a large moon might remain cozy for life over the long winter at Epsilon Eridani b. A thick atmosphere could retain heat, especially if it contains greenhouse gasses like carbon dioxide and methane. Geothermal activity or tidal forces from the planet's gravity could also induce heat on this extrasolar moon. Such is the case with Jupiter's moon Io and Saturn's moon Enceladus. And temperature swings likely wouldn't affect subterranean life on this world, should it exist there.



PLUTO'S ORBIT is small compared to the disk of dust and gas surrounding Epsilon Eridani. Astronomers used the James Clerk Maxwell Telescope to capture this false-color image of the star's disk. Bright colors show where dust is most abundant. The black area near this image's center indicates no dust or gas exist there. One possible explanation is one or more exoplanets swept up the material during their formation. JCMT/UKRIT

Searching for life

Drake's 1960s search for extraterrestrial intelligence, called Project Ozma, was a bold and visionary experiment — and the first scientific search of its kind. Today's astronomers continue to search for signs of life, albeit on a smaller scale.

Epsilon Eridani b is a compelling incentive for astronomers to build ever larger telescopes to investigate the planet and perhaps one day even identify moons circling it. Over the very long term, Epsilon Eridani b will be an exciting target for the first interstellar space probes to reconnoiter. Perhaps, one day, a robotic probe having an artificial intelligence equivalent to that of a toddler could even land at Epsilon Eridani b to curiously search for the genesis of life.

WEB EXTRA To learn more about astronomers' plans to visit Epsilon Eridani, visit www.Astronomy.com/toc.

BY MARTIN RATCLIFFE AND ALISTER LING

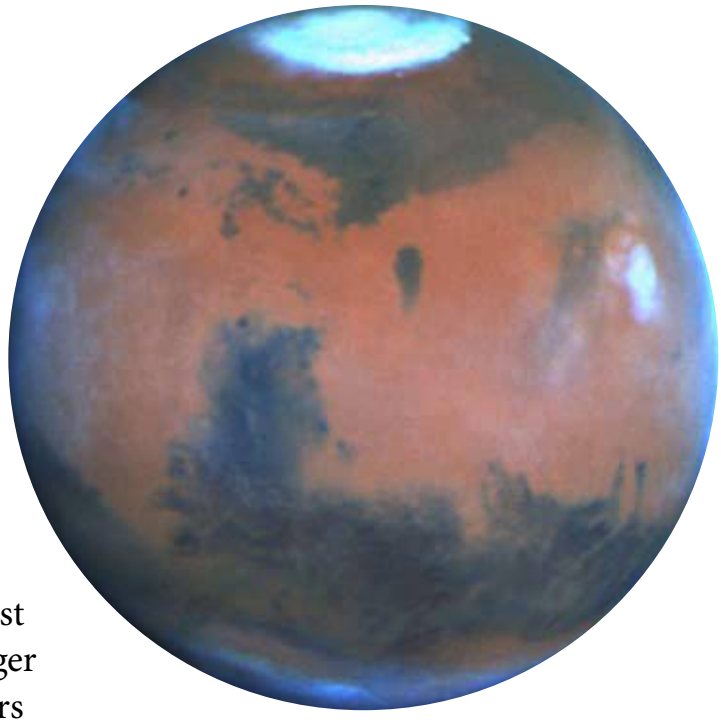
DECEMBER 07

Red Planet delights

It's Mars season again.

The Red Planet reaches its biennial peak this month, arriving opposite the Sun in our sky and closest to Earth. This is the best time to view Mars, whose disk appears larger than it will for the next 9 years. Before Mars climbs high enough for steady views, catch Neptune and Uranus through binoculars before they set. Saturn rises shortly before midnight and is joined by Venus before dawn.

Let's start our planet tour in the western evening sky. Some lucky observers might glimpse **Jupiter** before it slips below the horizon. Unfortunately, twilight claims the planet soon after the month begins.



MARS GROWS BIG for backyard observers in December, when it appears larger than it has since 2005 and shows great detail.
PHILIP JAMES (UNIVERSITY OF TOLEDO)/STEVEN LEE (UNIVERSITY OF COLORADO)/NASA

While you wait for your telescope to cool down for a perfect view of Mars, grab your binoculars to track **Neptune**. The outer planet's easterly motion against the background stars of Capricornus picks up speed in December. As the constellation of the Sea Goat sinks in the southwest, aim 2° straight up from Iota (ι) Capricorni to spy the 8th-magnitude planet.

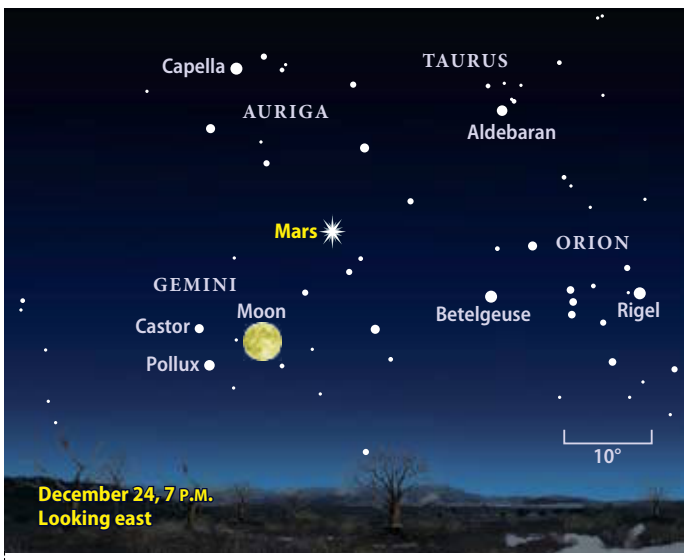
Uranus glows brighter than Neptune and is easier to spot in binoculars. As December opens, you'll find the 6th-magnitude planet in the south after sunset. It lies just east of 81 and 82 Aquarii. Uranus forms an isosceles triangle with these stars, which glow slightly fainter than the seventh planet. Although Uranus hardly changes position during December's first week, its easterly motion increases as the month progresses. By December's close, Uranus lies within 2° of Phi (φ) Aquarii.

Mars will top the planetary calendar for the next few

— *Continued on page 69*

48 Mars rules the night
69 Meteors from the Twins
69 Clementine: a lunar darling
70 When to view the planets
70 Saturn's moons
70 Comet 8P/Tuttle
71 Asteroid Ceres
71 The Moon visits Venus

Visible to the naked eye
Visible with binoculars
Visible with a telescope

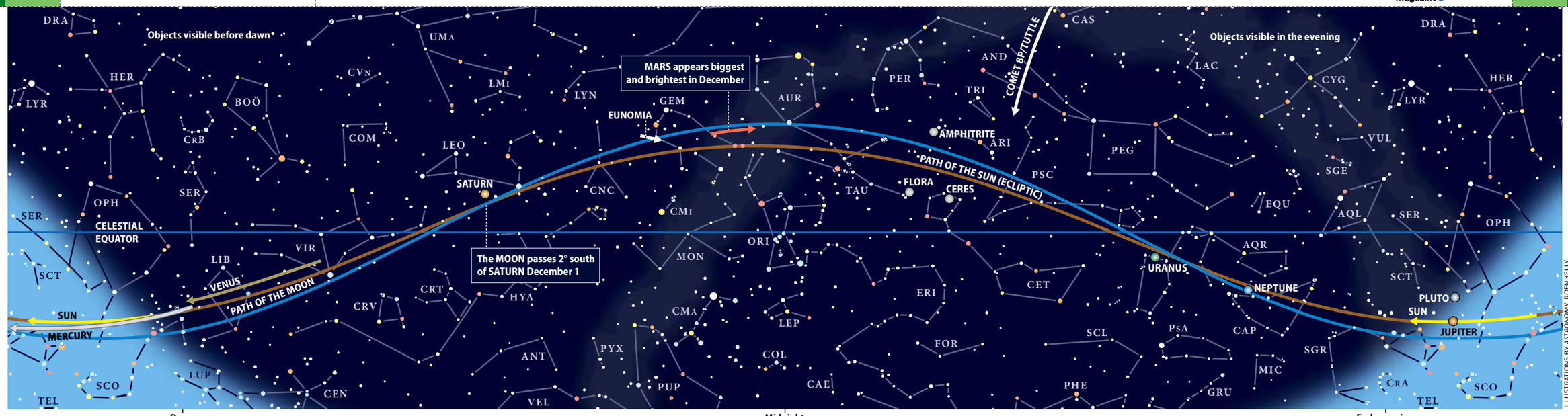


THE RED PLANET GLEAMS as it reaches opposition this month. Mars shines brighter than any star and dominates the sky from dusk to dawn. *ASTRONOMY:* ROEN KELLY

Planets this month

This map unfolds the entire night sky from sunset (at right) until sunrise (at left). Arrows and colored dots show motions and locations of solar system objects during the month.

Astronomy magazine



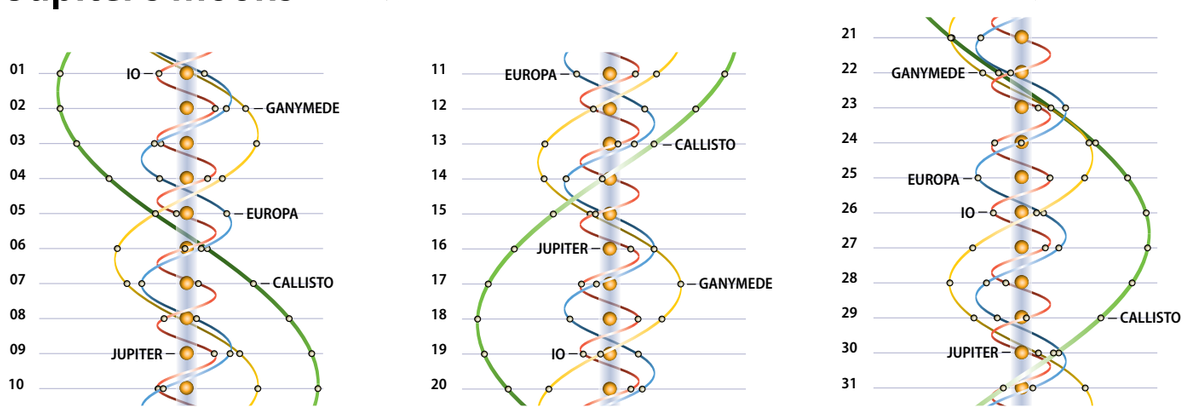
ILLUSTRATIONS BY *ASTRONOMY*: ROEN KELLY

To locate the Moon in the sky, draw a line from the phase shown for the day straight up to the curved blue line.

PLANETS	MERCURY	VENUS	MARS	JUPITER	SATURN	URANUS	NEPTUNE	PLUTO
Date	December 1	December 15	December 15	December 1	December 15	December 15	December 15	December 15
Magnitude	−0.8	−4.2	−1.5	−1.8	0.7	5.9	7.9	14.0
Angular size	4.9"	16.1"	15.8"	31.8"	18.5"	3.5"	2.2"	0.1"
Illumination	97%	71%	99%	100%	100%	100%	100%	100%
Distance (AU) from Earth	1.385	1.037	0.591	6.191	8.973	20.203	30.565	32.360
Distance (AU) from Sun	0.441	0.719	1.564	5.259	9.262	20.095	30.043	31.387
Right ascension (2000.0)	15h47.8m	14h37.3m	6h28.2m	17h41.9m	10h42.7m	23h05.4m	21h28.8m	17h53.4m
Declination (2000.0)	−19°34'	−12°56'	26°19'	−23°09'	9°54'	−6°41'	−15°11'	−17°07'

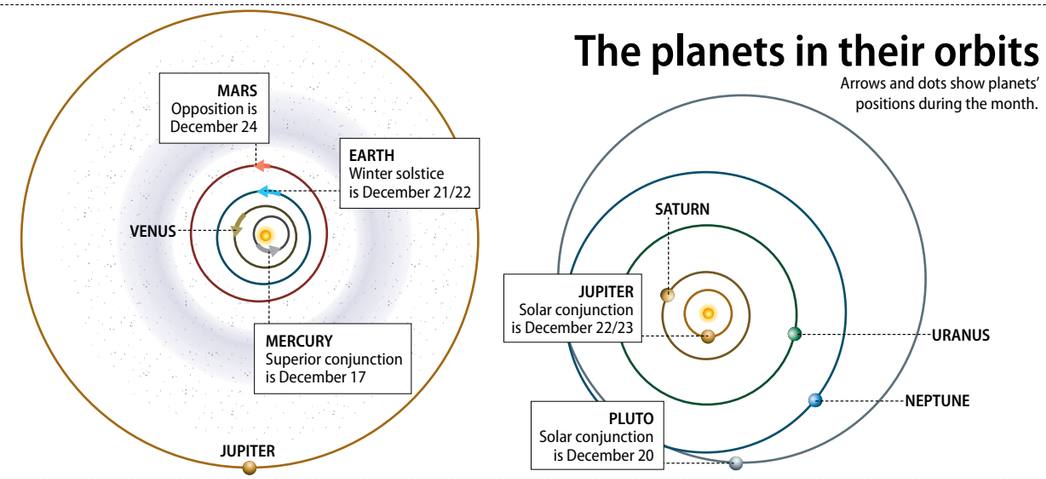
Jupiter's moons

Dots display positions of Galilean satellites at 7 P.M. EST on date shown. South is at top to match the view through a telescope.



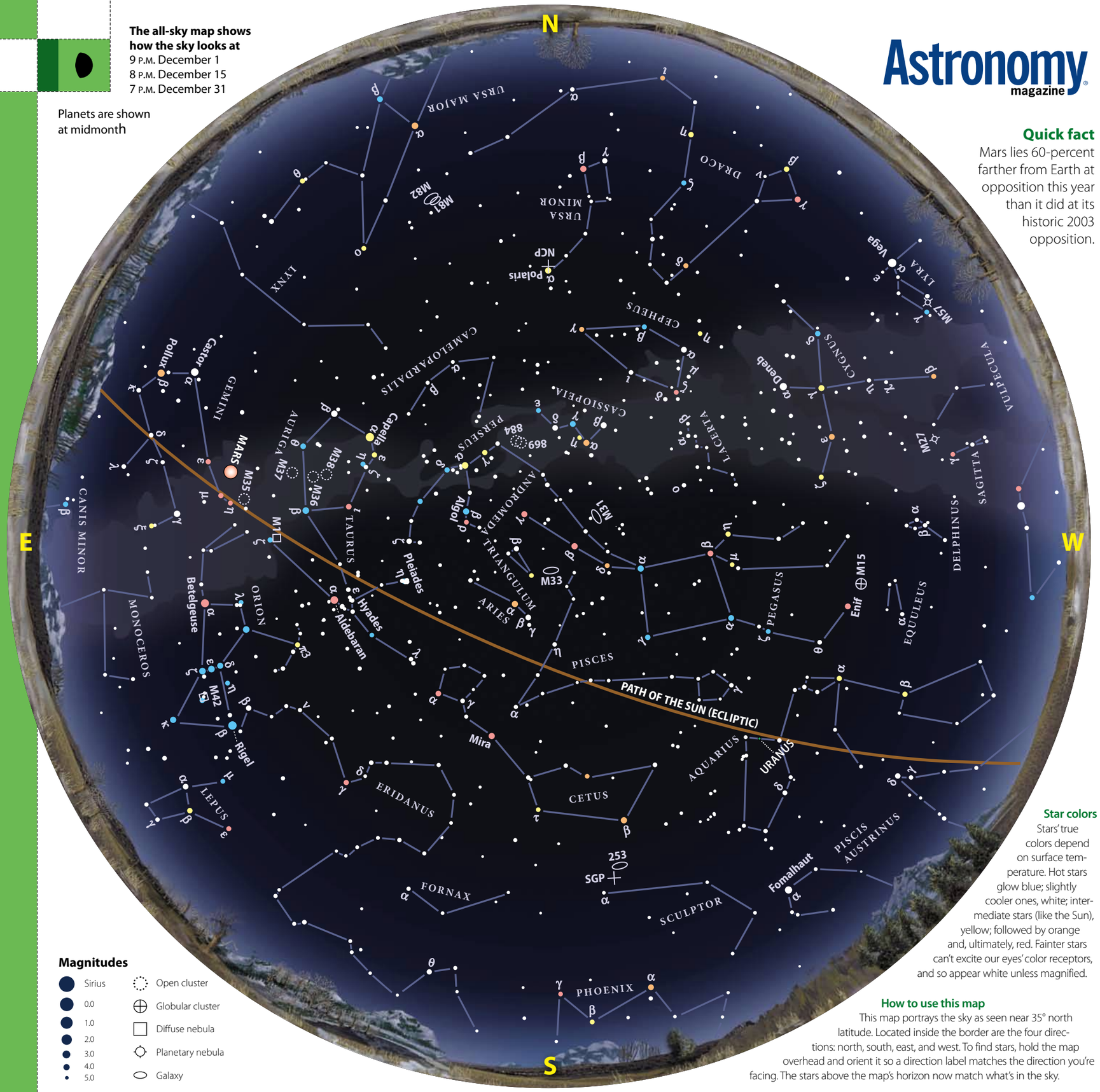
The planets in their orbits

Arrows and dots show planets' positions during the month.



The all-sky map shows how the sky looks at
9 P.M. December 1
8 P.M. December 15
7 P.M. December 31

Planets are shown at midmonth



Magnitudes

- Sirius
- 0.0
- 1.0
- 2.0
- 3.0
- 4.0
- 5.0
- Open cluster
- Globular cluster
- Diffuse nebula
- Planetary nebula
- Galaxy

Star colors
Stars' true colors depend on surface temperature. Hot stars glow blue; slightly cooler ones, white; intermediate stars (like the Sun), yellow; followed by orange and, ultimately, red. Fainter stars can't excite our eyes' color receptors, and so appear white unless magnified.

How to use this map
This map portrays the sky as seen near 35° north latitude. Located inside the border are the four directions: north, south, east, and west. To find stars, hold the map overhead and orient it so a direction label matches the direction you're facing. The stars above the map's horizon now match what's in the sky.

Astronomy magazine

Quick fact
Mars lies 60-percent farther from Earth at opposition this year than it did at its historic 2003 opposition.

NOTABLE OBSERVING DATE:
December 24, when Mars reaches opposition and peak visibility

december 07

SUN.	MON.	TUES.	WED.	THURS.	FRI.	SAT.
						[01]
[02]	[03]	[04]	[05]	[06]	[07]	[08]
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[30]	[31]					

ILLUSTRATIONS BY *ASTRONOMY*: ROEN KELLY

01 Last Quarter Moon occurs at 7:44 A.M. EST

The Moon passes 2° south of Saturn, 8 A.M. EST

05 The Moon passes 7° south of Venus, 8 P.M. EST

06 The Moon is at apogee (252,423 miles from Earth), 11:53 A.M. EST

09 New Moon occurs at 12:40 P.M. EST

14 Geminid meteor shower peaks

17 First Quarter Moon occurs at 5:18 A.M. EST

Mercury is in superior conjunction, 10 A.M. EST

18 Mars is closest to Earth (54.8 million miles away), 7 P.M. EST

20 Pluto is in conjunction with the Sun, 7 P.M. EST

22 Winter solstice occurs at 1:08 A.M. EST

The Moon is at perigee (224,200 miles from Earth), 5:14 A.M. EST

23 Jupiter is in conjunction with the Sun, 1 A.M. EST

Full Moon occurs at 8:16 P.M. EST

The Moon passes 0.9° north of Mars, 10 P.M. EST

24 **Mars is at opposition, 3 P.M. EST**

27 The Moon passes 0.6° south of Regulus, midnight EST

28 The Moon passes 3° south of Saturn, 5 P.M. EST

31 Last Quarter Moon occurs at 2:51 A.M. EST

WEB EXTRA For definitions of terms, visit www.Astronomy.com/glossary.

— *Continued from page 48*
months. On December 1, it stands 25° above the eastern horizon by 9 P.M. local time. Brightening as the month passes, it outshines Sirius during December's final 2 weeks.

The Red Planet reaches opposition December 24. It then lies opposite the Sun in our sky and remains visible all night. It also shines brightest at opposition, reaching magnitude –1.6. Mars' closest point to Earth comes 6 days earlier, however, on December 18, when it lies 54.8 million miles away. Opposition and closest approach don't coincide because Mars has a noticeably elliptical orbit.

Oppositions of Mars have a 15- to 17-year cycle. Some occur relatively near Earth, the case when Mars lies near its closest point to the Sun, called perihelion. Mars appears biggest and brightest at these "perihelic" oppositions. Some are farther away — the so-called aphelic oppositions. This year, Mars lies between these extremes. Even though it will be 4" smaller than at its 2005 opposition, Mars won't be this big or bright again until 2016. As an added benefit this year, the planet appears high in the sky from the Northern Hemisphere.

Naked-eye observers can track Mars' westward motion against the stars of Gemini. The Red Planet currently plies the middle of its retrograde loop. December begins with Mars 0.6° from 3rd-magnitude Epsilon (ε) Geminorum. The planet's path carries it back into Taurus by year's end.

Martin Ratcliffe *is the former president of the International Planetarium Society.* **Alister Ling** *is a meteorologist for Environment Canada.*

TWIN TREATS FROM GEMINI

After the waxing crescent Moon sets in midevening December 14, the background sky darkens for a great view of the Geminid meteor shower. Active from December 7 to 17, the Geminids feature plenty of bright meteors and rank among the best showers of the year.

The shower's radiant lies in Gemini the Twins, which rises shortly after sunset from North America and stands halfway to the zenith at 10 P.M. local time. This offers meteor watchers a full night of enjoyable observing. Of course, Mars now rules this constellation. The meteors simply add an exclamation point to the spectacle.

As the radiant approaches the zenith soon after midnight, observers under dark skies could see 100 or more meteors per hour. The Geminid shower is one of the few where the radiant climbs high enough for attentive viewers to see close to the maximum rate possible.

GEMINID METEORS STREAK across the sky the night of December 14/15. After the Moon sets in midevening, you could see 120 meteors per hour from a dark site. PIERRE MARTIN

SEE PAST THE POLE

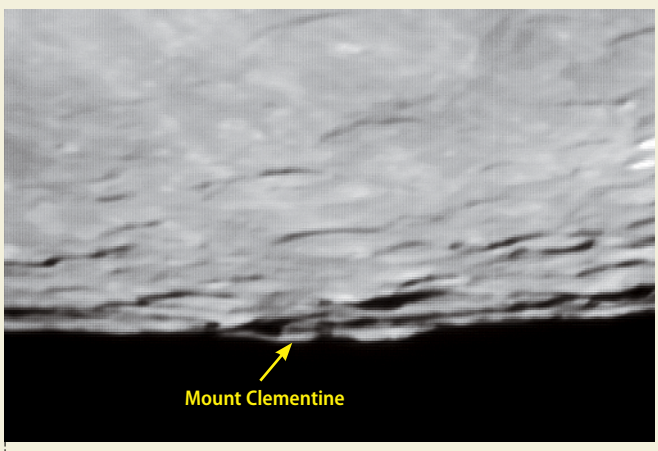
This month's lunar feature lies on the Moon's farside, beyond the south pole. Mount Clementine is the easiest backside feature to see — when the timing's right. You have 4 nights to visually climb its 3-mile-high summit this month, before it disappears from view.

When the Moon lies north of the ecliptic (the plane of Earth's orbit around the Sun, depicted as a brown line on our all-sky map), we can peer a bit "under" its south pole. At Full Moon (December 23), topography normally disappears because every hill hides its own shadow. But our viewing angle near the south pole at this month's Full Moon turns a flat scene three dimensional.

Two mountains jut from the rippling limb in the picture above. The one at left is Mount Clementine. The bump in front of it casts a shadow all the way to Clementine's base. It's a treat to watch this shadow step from lunar southwest, to south at Full Moon, then east the day after (when this image was taken).

If you can see features beyond this picture's limb, you've spotted the farside craters Shackleton and Faustini. The mountain on the right, however, lies on the pole's nearside.

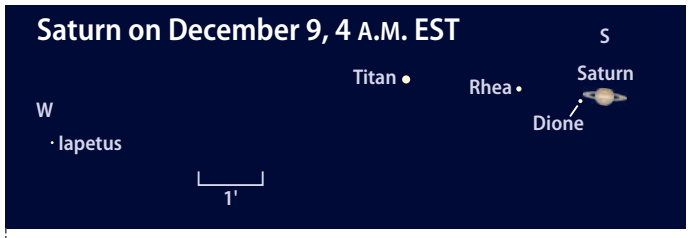
The Full Moon's glare is close to unbearable in larger instruments. If this happens to you, use a dark blue or green filter.



MOUNT CLEMENTINE lies just beyond the Moon's south pole, but a favorable libration around December 23 will let you spy its 3-mile-high summit. ALISTER LING

/// WHEN TO VIEW THE PLANETS

EVENING SKY	MIDNIGHT	MORNING SKY
Mars (east)	Mars (south)	Venus (southeast)
Jupiter (southwest)	Saturn (east)	Mars (west)
Uranus (south)		Saturn (southwest)



SATURN'S MOONS offer good views any clear night. Look for Iapetus near its peak brightness in early December. *ASTRONOMY:* ROEN KELLY

On December 23, the night before opposition, a Full Moon lies near Mars. At the end of twilight, the Moon stands its own diameter north of the Red Planet. Three hours later, the Moon's orbital motion will have carried it 3 Moon-widths east of Mars.

As dazzling as Mars looks to the naked eye, a telescope should be your instrument of choice. The diameter of Mars' disk peaks at 16". To see much detail on a disk this size, beginners likely will need an 8-inch or larger scope. (Experienced observers will do well with a 6-inch scope.) Whatever scope you use, atmospheric "seeing" will determine how sharp the disk appears. Waves of air roll across our sky, constantly cajoling light waves and smearing the image. There's little visual observers can do but wait for moments of steady seeing. Be patient — these moments are brief and precious.

Technology can be a help. Recording 1- to 2-minute-long video sequences can capture those fleeting moments of good seeing. Then, freely available image-stacking software lets you sort the wheat from the chaff, so to speak. Skill at manipulating software tools will develop with time, and can replace the expertise of eye, memory, and artistic ability.

What can you see on Mars? Remember that Mars takes 37 minutes longer than Earth to complete one rotation on its axis. As a result, if you view at the same time each night, Mars appears to rotate backward

TUTTLE PROVIDES SOME COMETARY CHARM

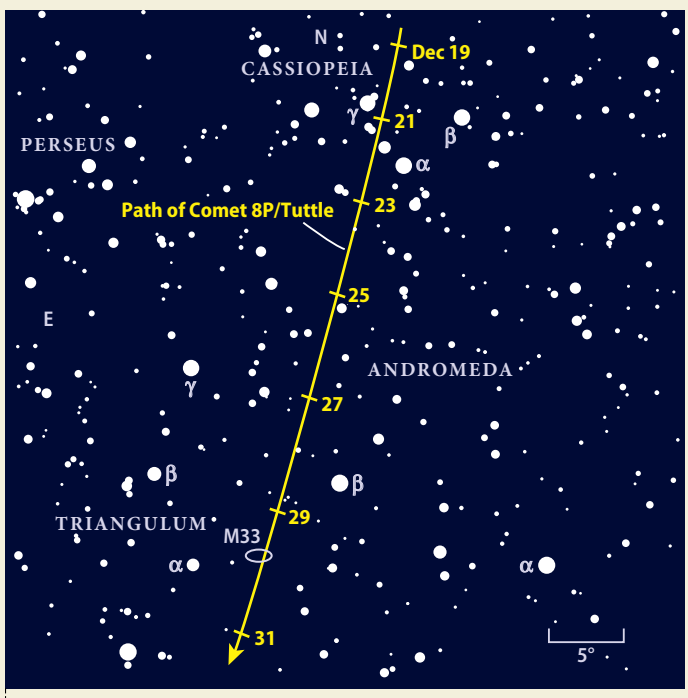
Astronomers of all stripes get excited about naked-eye comets. Although periodic visitor 8P/Tuttle won't approach Comet McNaught's spectacular appearance last winter, it will be bright enough to glimpse from a dark site. And the view through binoculars should be great at December's close, when the comet passes the Pinwheel Galaxy (M33) high in a dark sky.

Before reaching its peak of 5th to 6th magnitude, Tuttle starts the month at 9th magnitude near Polaris. Almost from one night to the next, you may notice the coma getting brighter and the tail growing longer. Use a full range of magnifications, from binoculars to high-powered telescope views. You usually face a trade-off between the delicate structure visible at the eyepiece and the graceful form and beauty with binoculars, so hit it with everything you've got.

Unfortunately, the Moon will be near full phase when Tuttle passes the Pac-Man Nebula (NGC 281) December 22/23. Still, make the effort to look that night because you may see an uncommon sight — a tail pointing toward the Sun instead of away.

Such anti-tails turn out to be illusions of perspective. Make a triangle with a sheet of paper, and think of this as a comet's fan-shaped tail. Now, with the point toward you, slowly tilt the sheet so it lies edge-on. You'll see the edges sticking out on both sides of the point — a tail on each side of the coma.

North Americans should be ready as darkness falls December 30, because the comet has just passed the Pinwheel Galaxy and will be only a degree away by midnight. Two pictures taken a few hours apart will make a stereo pair that can be viewed in pseudo 3-D.



COMET 8P/TUTTLE should glow bright enough to see with the naked eye late this month, but you'll get the nicest views through binoculars or a telescope. *ASTRONOMY:* ROEN KELLY

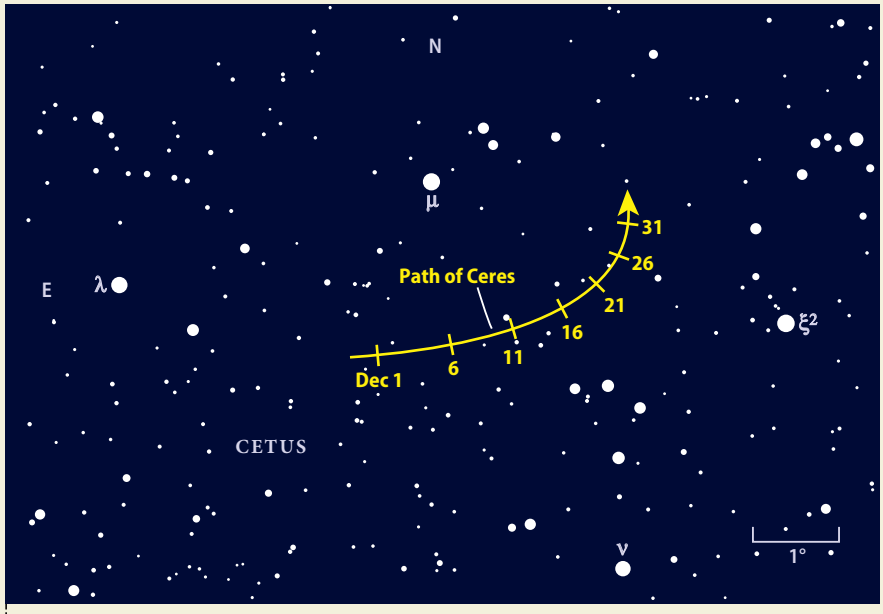
Comet 8P/Tuttle is also the parent comet to this month's annual Ursid meteor shower. Unfortunately, a Full Moon will wash out the shower's December 22/23 peak.

A TAIL OF THE WHALE

You shouldn't have a problem using a small telescope to track down the asteroid 1 Ceres. This month, it arcs past a couple of modestly bright stars in the tail of Cetus the Whale. Glowing at 8th magnitude, Ceres shows up through binoculars under a dark sky, but you'll need a scope to follow it from the suburbs. On the positive side: Ceres stands out from the background because Cetus doesn't have many faint stars to swamp it.

Avoid trying to find Ceres from December 18 to 24, when moonlight makes it hard to spot the Whale's tail star, Mu (μ) Ceti. From Mu, drop 2° south and you've got the right field. The only time you might confuse Ceres with background stars is from the 10th to the 15th, when it passes through a right-angled triangle that spans 30′, the Moon's apparent size.

This stellar trio provides the opportunity for a simple project to track an asteroid's movement. Sketch the positions of the four dots, note the date, time, and orientation of the field, then return to the same field a night or two later and make another sketch. Ceres will stand out as the obvious interloper because it will have changed position.



CERES PLIES CETUS this month, moving through the Whale's tail. The 8th-magnitude asteroid will be an easy binocular target from a dark-sky site. *ASTRONOMY*: ROEN KELLY

Ceres measures 595 miles across — the largest asteroid orbiting between Mars and Jupiter — and currently lies 180 million miles from our pale blue planet. Astronomers have observed a periodic rise and fall in Ceres' brightness, indicating it rotates once every 9 hours. Hubble images reveal a bright spot that may be a fairly fresh crater.

slightly. If you observe through the night beginning in early December, by month's end you'll have seen the entire globe.

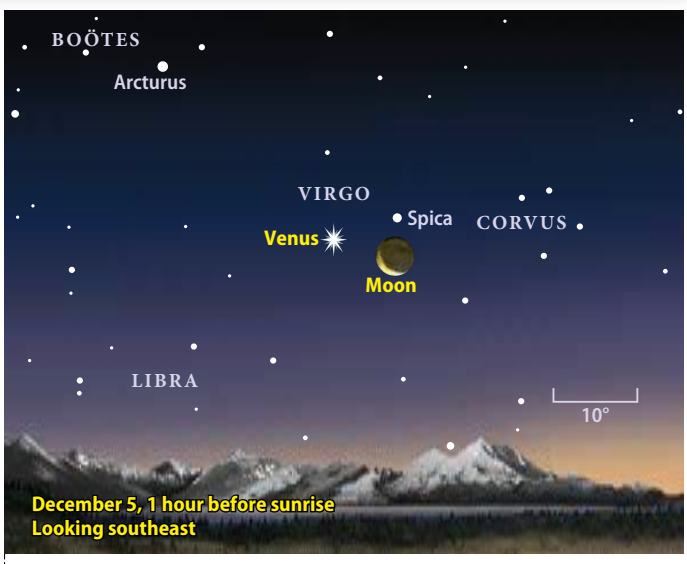
Spring begins in Mars' northern hemisphere on the planet's December 9 equinox. Early in the month, around midnight for North American observers, the bright Amazonis desert is on view, with the only major dark feature being the southern hemisphere's Mare Sirenum. By mid-December, Solis Lacus and Sinus Meridiani offer many dark features. And at opposition, Syrtis Major appears conspicuous on the martian disk around midnight.

Midnight also heralds the appearance of **Saturn**. The ringed planet rises just before the witching hour December 1, and 2 hours earlier by year's end. Regulus, the brightest star in Leo the Lion, rises about 40 minutes before Saturn. At midnight on Christmas Eve, when Mars dazzles nearly overhead, Saturn lies nearly 25° above the eastern horizon.

Saturn's rings appear closer to edge-on now than they have since 1997. Their slight tilt gives a nearly complete view of the planet's 19"-diameter disk. Saturn's shadow falls on the rings near the globe's western limb. This creates a striking three-dimensional effect, best seen in November and December.

Iapetus, Saturn's two-faced moon, lies west of Saturn this month. With its brighter face fully turned in our direction, Iapetus peaks at magnitude 10.1 during the month's second week. Titan, Saturn's brightest moon, lies due north of the planet December 4/5 and 20/21, and south of the planet December 12/13 and 28/29.

Venus lies level with Virgo's brightest star, Spica, and rises shortly before 4 A.M. local time December 1. Watch for the waning crescent Moon to join the pair on the 5th. The Moon's 16-percent-lit crescent contrasts with the telescopic view of Venus, which shows a disk 17" across that's two-thirds illuminated. Venus crosses into Libra December 12, and stands between Alpha (α) and Beta (β) Librae on the 19th.



THE MOON AND VENUS lie next to each other December 5. This meeting of the two brightest nighttime objects will be worth rising early to see. *ASTRONOMY*: ROEN KELLY

Innermost **Mercury** reaches superior conjunction December 17 and remains hidden in the Sun's glare all month.

Winter begins December 22 at 1:08 A.M. EST. This marks the instant when the Sun lies farthest south in Earth's sky.

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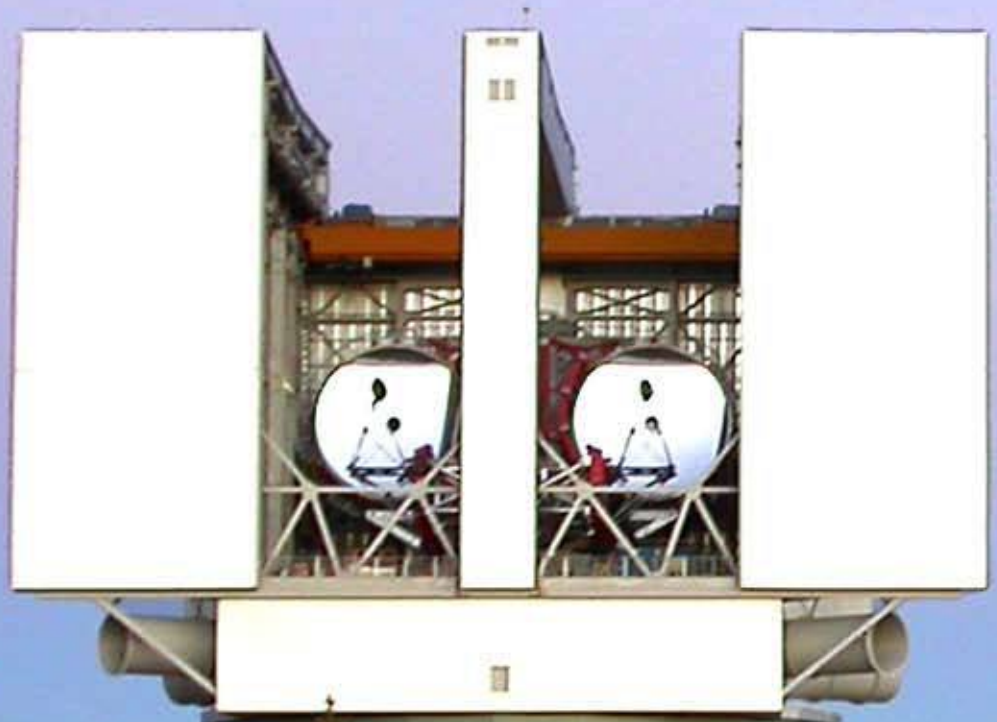


TWO NEW "EYES" take in the sky at the Large Binocular Telescope (LBT) Observatory on Mount Graham in Arizona. This fall, astronomers made their initial observations using both telescopes, achieving "first binocular light." LARGE BINOCULAR TELESCOPE CORPORATION (LBTC)/JOHN HILL

A unique observatory now taking shape atop Arizona's Mount Graham will one day best the Hubble Space Telescope. /// **BY BRUCE DORMINEY**

Telescope opens *both* eyes

LBT'S LARGE BINOCULAR CAMERA reveals the richness of open cluster M67. Astronomers took the tri-color mosaic earlier this year as part of the camera's commissioning. LBTC/EMANUELE GIALLONGO, VINCENZO TESTA, STEFANO GALLOZZI (ROME OBSERVATORY)

The world's largest telescope is finally turning its twin "eyes" to the sky. In September, from its perch atop southeastern Arizona's 10,500-foot (3,200 meters) Mount Graham, the Large Binocular Telescope (LBT) made its first observations using both of its twin main mirrors.

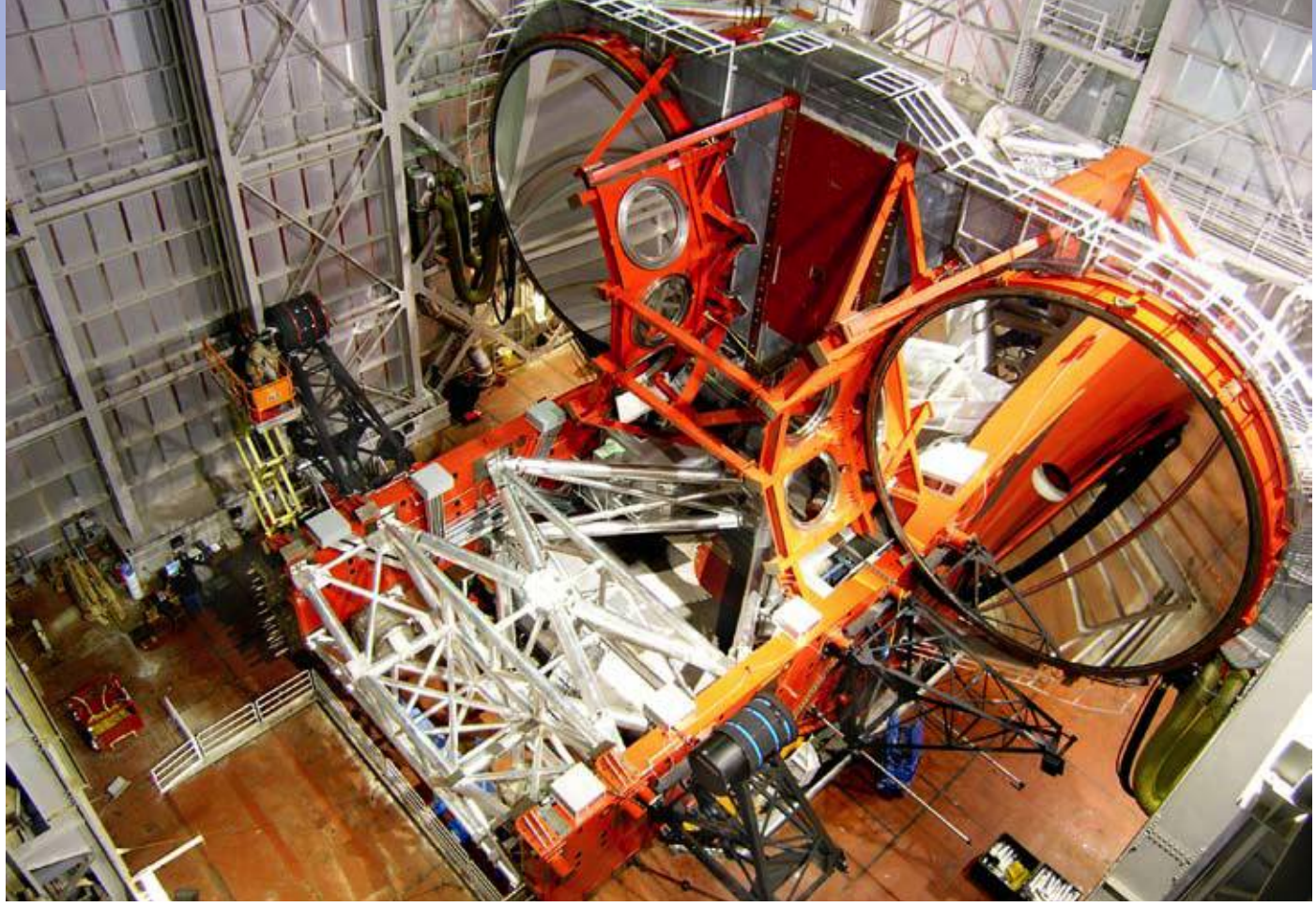
After 20 years of design and construction, the LBT has finally started doing astronomy. But the $130 million instrument won't reach its full observing potential until 2010. When it does, though, no optical scope in existence will match its resolution. The LBT will produce images nearly 10 times sharper than the Hubble Space Telescope, currently astronomy's gold standard.

Giant binoculars

LBT Technical Director John Hill explains that, whatever their specific cosmic interest, astronomers want two things in a telescope: large light-collecting area and high resolution. The LBT provides both — in spades.

Its two 8.4-meter primary mirrors sit on the same steerable mount. Their centers are 14.4 meters apart, providing a collecting area equivalent to a single 11.8-meter telescope. But, because of its binocular arrangement, the telescope will have the resolution of a 22.8-meter telescope. When both sides are fully operational, astronomers will be able to operate them separately or together.

The LBT's wide field of view, spatial resolution, and sensitivity promise image quality equal to a space-based scope. They should help scientists untangle conundrums about how our universe unfurled



LBT'S TWIN 8.4-meter primary mirrors are spaced 19.7 feet (6 meters) apart in an altitude-azimuth mount. With its binocular design, the LBT can match the resolution of a 22.8-meter telescope. LBTC/RAY BERTRAM

HOW DOES LBT'S ADAPTIVE OPTICS WORK?

Ground-based interferometry would never be possible if not for the correcting power of adaptive optics, a method of canceling out distortion caused by atmospheric turbulence. But for adaptive optics to do its job, observatories first need to measure the shape of such turbulence several hundred meters above the telescope.

Laser and natural guide stars probe turbulence 1,000 times per second. Information from these atmospheric snapshots determine how deformable mirrors in the telescope's optics must warp to compensate for the atmosphere.

On the LBT, the scope's 35.8-inch (91 centimeters) secondary mirrors will perform these corrections. Once they're installed in 2009, the secondaries' 672 magnetic actuators will adjust the mirrors and remove distortions. — *B. D.*

Bruce Dorminey *is the author of* Distant Wanderers: The Search for Planets Beyond the Solar System *(Copernicus Books, 2001). His most recent* Astronomy *article was "What lurks between galaxies?" in September 2007.*

from the Big Bang into its current structure, with galaxies of all shapes and sizes congregating in massive galaxy clusters separated by vast voids.

By the end of 2009, when all planned mirrors and instruments are installed, the LBT will be capable of seeing wavelengths from the near-ultraviolet down to the submillimeter range, which abuts the radio spectrum. Its *forte* will be wide-field surveys of faint objects — from the faintest galaxies ever observed to planets circling Sun-like stars. The LBT will offer new details about how dusty interstellar clouds "spin down" to form nascent stars and planetary systems. And it may even determine how often solar systems like ours blossom in the Milky Way Galaxy.

Rocky road

The LBT achieved first light with a single primary mirror in October 2005. Science observations began only in January 2007 — a year and a half behind schedule. Then came the worst southern Arizona weather LBT Director Richard Green can remember.

"Commissioning took longer than normal because below-freezing temperatures caused technical issues with the primary mirror," Green says. "We made a dozen small changes to its support system and it worked flawlessly, but it took about a year to accomplish that. What's amazing about this project is that almost everything is

being done for the first time in some way. It just takes time."

Astronomers expect to see scientific papers from the LBT's first observations at January's American Astronomical Society meeting. However, routine science using all of the telescope's planned instruments isn't expected until 2010.

When research does begin, the principal U.S. investors — the University of Arizona, the Ohio State University, and the Tucson-based Research Corporation — will respectively get a quarter, about one-sixth, and one-eighth of the observing time. Nearly half of the LBT's observing time will go to partner institutions in Italy and Germany.

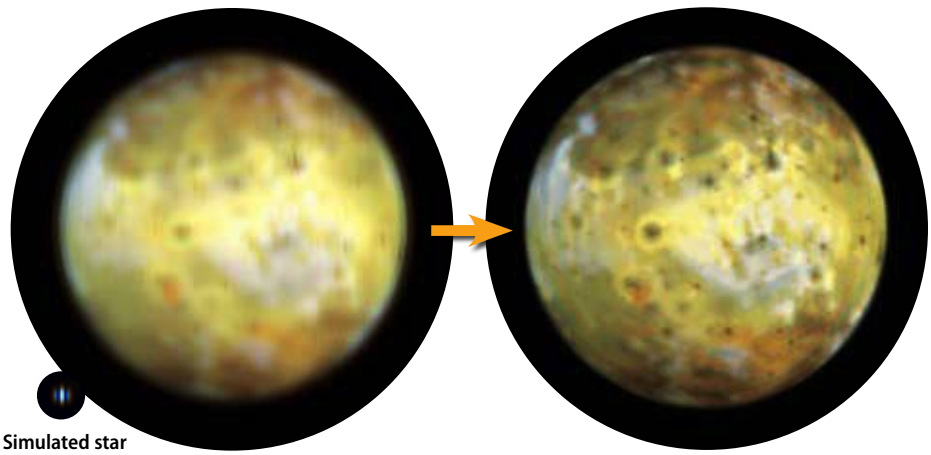
Fast, deep cameras

Science observations actually began with the first of two Italian-built Large Binocular Cameras (LBCs) installed on the telescope. Emanuele Giallongo, Rome Observatory's director and the LBC principal investigator, says he and colleagues will carry out wide-field surveys of distant galaxies to better understand how galaxies began clustering and clumping as early as 1 billion years after the Big Bang. "The LBC is very efficient: In a few hours you can reach 26.5 magnitude," he notes. That's 10 times faster than other cameras.

Astronomers already have used the first Large Binocular Camera to survey Kuiper Belt objects at the outer edge of our solar system and to follow up on gamma-ray bursts (GRBs) halfway across the universe. David Trilling, an astronomer at the University of Arizona in Tucson and the principal investigator on the LBT's Kuiper Belt Survey, says his team completed 8 hours of observations in the visible spectrum. They were searching for ancient so-called classical Kuiper Belt objects (KBOs) 12 to 19 miles (20 to 30 kilometers) across. Such objects lie well beyond Pluto's orbit, on circular orbits in the ecliptic's plane.

THE FAMOUS CRAB NEBULA (M1) supernova remnant was an LBT target during tests in spring 2007. The 36-megapixel Large Binocular Camera produced this true-color image using one of the telescope's primary mirrors. LBTC/VINCENZO TESTA ET AL. (ROME OBSERVATORY)

ASTRONOMERS IMAGED the edge-on spiral galaxy NGC 891 in Andromeda October 12, 2005, as a "first light" milestone for the LBT's first mirror. The image required ten 30-second exposures using the Large Binocular Camera, placed at the first mirror's prime focus. LBTC



A SINGLE LBT IMAGE is sharpest in one direction and fuzziest perpendicular to it. These simulated views of Jupiter's moon Io and a single star show this effect of the scope's binocular aperture. The sharpest image occurs in the direction containing both mirrors (horizontally, in this case). The perpendicular direction (vertically, here) shows the lowest resolution.

BY TAKING SEVERAL IMAGES a night, LBT astronomers can achieve the resolution of a 22.8m, circular-aperture scope. As the night progresses, targets rotate relative to the line between the two mirrors. This means the region of best resolution also changes across the target. Combining the images raises LBT's resolution. STAR AND IO IMAGES: LBTC/E. K. HEGE AND J. R. P. ANGEL

When both cameras are working on each side of the telescope, Trilling says he will benefit from observations in two separate wavelengths. The first camera is sensitive to light in the blue portion of the spectrum, while the second will be more attuned to red light. "Comparing the flux from two different wavelengths will roughly tell us if the surface [of a KBO] is rock or ice — and even what type of ice it might be," he explains.

Further afield, Notre Dame astronomer Peter Garnavich led an optical survey of gamma-ray bursts. His team has already published eight circulars on LBT observations of six GRBs at distances from 6 to 12 billion light-years. Eventually, Garnavich's team will use the LBT to follow up on GRBs located by NASA's Swift satellite.

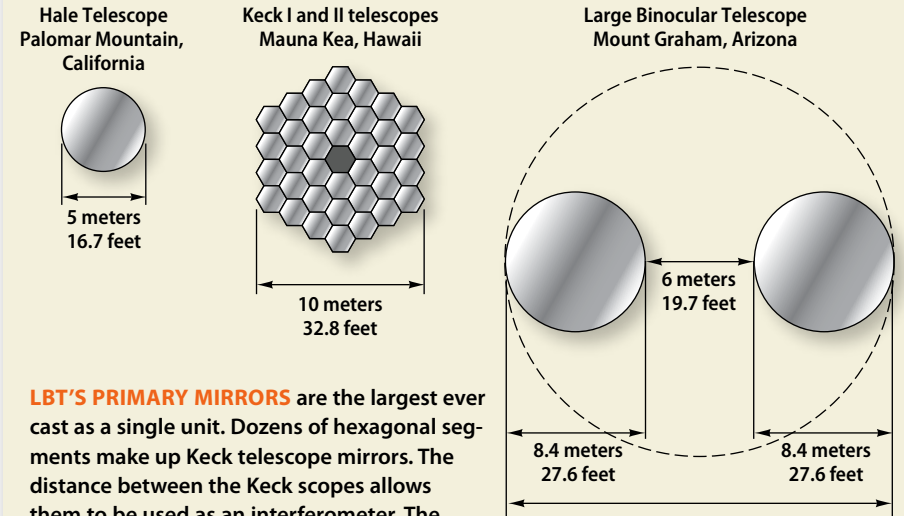
"Most of the Swift-discovered bursts have very faint afterglows, making them harder to follow for long periods with small telescopes," Garnavich says. "Since GRB afterglows can be followed with smaller telescopes in minutes to hours after the burst, we try to pick a time when the burst is too faint for other telescopes." The LBT is well suited for catching fading GRB afterglows.

The birth of galaxies

Unlike any current ground- or space-based telescope, the LBT's unique power presents an opportunity to probe the universe's first brush with galaxy formation some 500

THE LBC IMAGED imaged NGC 6946, a face-on spiral in Cepheus September 18, 2006. Astronomers created this composite of images through ultraviolet, blue, and green filters using the blue-optimized Large Binocular Camera and a single primary mirror. The image proved the telescope's tracking and camera were nearing the reliability astronomers expected. LBTC/VINCENZO TESTA AND CHRISTIAN DESANTIS (ROME OBSERVATORY)

How the Large Binocular Telescope compares to other big scopes



LBT'S PRIMARY MIRRORS are the largest ever cast as a single unit. Dozens of hexagonal segments make up Keck telescope mirrors. The distance between the Keck scopes allows them to be used as an interferometer. The Keck interferometer bests LBT's resolution, but LBT has a field of view about 10 times wider.

ASTRONOMY: THEO COBB

million years after the Big Bang.

The LBT's sensitivity will allow astronomers to take spectra — light broken into its constituent colors — in a way that neither the Hubble nor the Spitzer space telescopes can.

LUCIFER, the LBT near-IR Spectroscopic Utility with Camera and Integral Field Unit for Extragalactic Research, is due for installation in early 2008. This German-built imager and spectrograph specifically targets objects observable in the near-infrared.

The Ohio State University is building MODS, the Multi-Object Double Spectrograph. Optimized for observations from the optical to the ultraviolet, MOD is scheduled to begin routine science observations by late 2009.

LUCIFER will take images and spectra of objects ranging from nearby low-mass stars to the most distant quasars. MODS will take spectra of the faintest objects possible, from stars to galaxies, while measuring their compositions and distances.

"The LBT will be essential in following up what Hubble sees in the infrared," says Richard Ellis, a Caltech astronomer who has been studying galaxy formation for more than 30 years. That's in part because the LBT will enable astronomers to use new ground-based technology that far exceeds Hubble's current instrument package.

Ellis believes the LBT will explore the cosmos as it was some 500 million years after the Big Bang. That's at the end of the so-called Dark Ages, roughly when the first stars formed. No telescope will take us farther back until the 2013 launch of Hubble's successor, the James Webb Space Telescope.

"Hubble images have shown us what we're missing," Ellis explains, "so we need spectra of these faint galaxies to place them in time. We have huge surveys of the morphologies and masses and star-formation rates of thousands of galaxies at different points in cosmic history. But it's the understanding that always lags behind."

In fact, he says, the LBT would be "astonishingly effective" if a single instrument could merge its light-combining interferometry with its spectra-capturing

ability. Using interferometry in a spectroscopic mode, the LBT would be able to look at distant galaxies in the process of merging and see how each subcomponent is moving within the merger. This, in turn, would give cosmologists new insight into how the earliest galaxies evolved into life-bearing, carbon-rich, grand spirals like our own Milky Way. A German-initiated study for such a camera is already under consideration, and a working device may be installed on the telescope by 2012.

Seeing exoplanets

Theorists believe the universe's carbon — the stuff that forms the basis of life as we know it — reached its production peak some 7 billion years ago. Thus, the seeds of life were planted when the universe was only half its current age. How did we get from there to here? Do solar systems like ours lurk around other nearby stars? This lonely mountaintop structure should provide some tangible answers.

Astronomers have found more than 200 planets circling Sun-like stars. Many are gaseous Jupiter-like objects in short, often highly elliptical, orbits. Thus, the question remains: Does nature make solar systems like ours — with giant planets in distant, circular orbits — in abundance?

NASA is partially funding a 4-year LBT survey that will use an instrument known as the LBT Interferometer (LBTI) to learn more about the technology necessary for the space agency's own future planet-hunting missions. The LBT's sensitivity at mid-infrared wavelengths is perfectly suited to look for Jupiter-mass planets less than a billion years old.

Phil Hinz, an astronomer at the University of Arizona and principal investigator on the LBTI, says the telescope will scour the area around 80 young, nearby, Sun-like stars. It will search for dust left over from planetary formation in systems that may be similar to our own. Hinz says the LBT will also use an optical coronagraph, which blocks out a star's overwhelming light, as part of the same survey to take snapshots of young Jupiters.

The best hope for such LBTI science is the beginning of 2010. That's when astronomers anticipate both images and low-resolution spectra of such planets. By then, construction may have begun on an ambitious LBT follow-on project.

FOR THE LBT, INTERFERENCE IS A GREAT THING

In 2009, with the LBT's secondary mirrors installed, the telescope will use technical wizardry to produce high-resolution images of almost anything on the sky. The process, called optical interferometry, uses light's wavelike nature to combine the incoming photons. This includes the ability to combine multiple images to gain the resolution of a larger scope.

But there's more. The LBT takes advantage of constructive and destructive interference. When the peaks and troughs of incoming light waves from both mirrors coincide almost exactly, they add together for a brighter image. When the light peaks from one mirror align with the troughs from another, the waves cancel out.

But because these matchups are never perfect, the resulting images always contain bright and dark fringes where, respectively, the light waves add together or subtract. "Instead of seeing round dots for all the stars, you would see these round dots crossed by fringes," says Tom Herbst, chair of the LBT scientific advisory committee at Germany's Max Planck Institute in Heidelberg.

LINC-NIRVANA, a German-built interferometric instrument, is due for installation on the LBT by the end of 2009. It will use constructive interference in the near-infrared to enhance LBT's view of faint objects over a wide field. Herbst is the instrument's principal investigator.

The LBT Interferometer will use destructive interference for its "nulling mode." Astronomers will delay the beam from one of the telescope's apertures to produce a 180° phase shift, causing the light waves' peaks and troughs to cancel out one another. Dark fringes will appear across the combined image, and this, in turn, will block out part of the sky like Venetian blinds across an open window. — *B. D.*

LIGHT AND DARK fringes cross an LBT image displayed on a monitor in the telescope's office-like control room. LBTC

The next superscope

An international consortium with key participation by the University of Arizona and Carnegie Observatories already is planning the Giant Magellan Telescope (GMT). The estimated $500 million GMT would consist of seven LBT-sized, 8.4m mirrors mounted on a single steerable mount. This leviathan may see first light at Las Campanas Observatory in Chile by 2017.

Once GMT wraps up, astronomers may push for a more difficult follow-on project. In cold, dry, infrared-friendly Antarctica, a telescope like GMT would be an unparalleled planet-finder. "In Antarctica, with something like the GMT," Hinz says, "you would be on the edge of being able to detect an extrasolar Earth."

It's hard to imagine such a billion-dollar project getting off the ground today. But if a GMT clone ever does sprout to scan Antarctic skies, it will be the culmination of a technological and scientific journey that began with giant binoculars on an Arizona mountaintop. A

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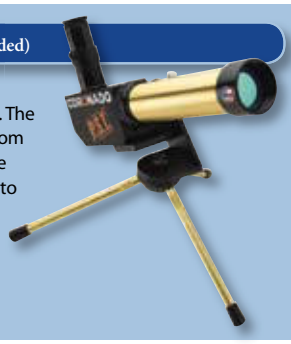

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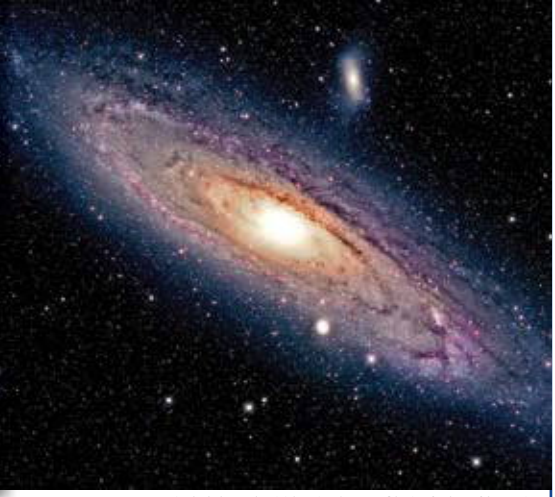

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Prizes and Odds of Winning. One drawing will be held on or around February 19, 2008, for the following awards: One (1) Grand Prize consisting of a 10' LX200R Telescope (retail value $3,699.00). One (1) First Prize consisting of a 12' LightBridge Telescope (retail value $999.00). One (1) Second Prize consisting of a Coronado PST (retail value $599.00). One (1) Third Prize consisting of a mySKY™ (retail value $399.00). One (1) Fourth Prize consisting of a Series 4000 Eyepiece Set (retail value $299.00). Ten (10) Fifth Prizes each consisting of a one-year subscription to *Astronomy* magazine (retail value $42.95 each). Cash equivalents of merchandise will not be awarded. Substituting prizes is not allowed. Any applicable federal, state, and/or local taxes are the responsibility of the winner. Odds of winning depend on the number of entries received. Total circulation for *Astronomy* magazine is 131,288. Sweepstakes void in Quebec and void where prohibited.

Validation and Acceptance. Winners in The *Astronomy* 2008 Winter Sweepstakes will be selected in a random drawing. Canadian prize awards subject to skill test requirement. By entering the sweepstakes, participants agree to be bound by these official rules and all decisions of Kalmbach Publishing Company. Sweepstakes entries void if not legible, not completed in full, not obtained legitimately, or if forged, photocopied, mechanically reproduced, late or tampered with. The potential winners may have to sign and return an Affidavit of Eligibility, publicity release and Release of Liability within fourteen (14) days of notification. In the event of non-compliance, alternate winners will be randomly drawn. No responsibility is assumed for lost, stolen, misdirected or late entries or notifications. All sweepstakes entries become the property of Kalmbach Publishing Co. and will not be returned.

Winner's List. For a list of winners, send a stamped, self-addressed envelope to: The *Astronomy* 2008 Winter Sweepstakes Winners List, P.O. Box 1612, Waukesha, WI 53187-1612. Residents of FL, VT, and WA may omit stamp. Requests must be received by March 20, 2008. Or check the *Astronomy* web site (www.Astronomy.com) after March 1, 2008.

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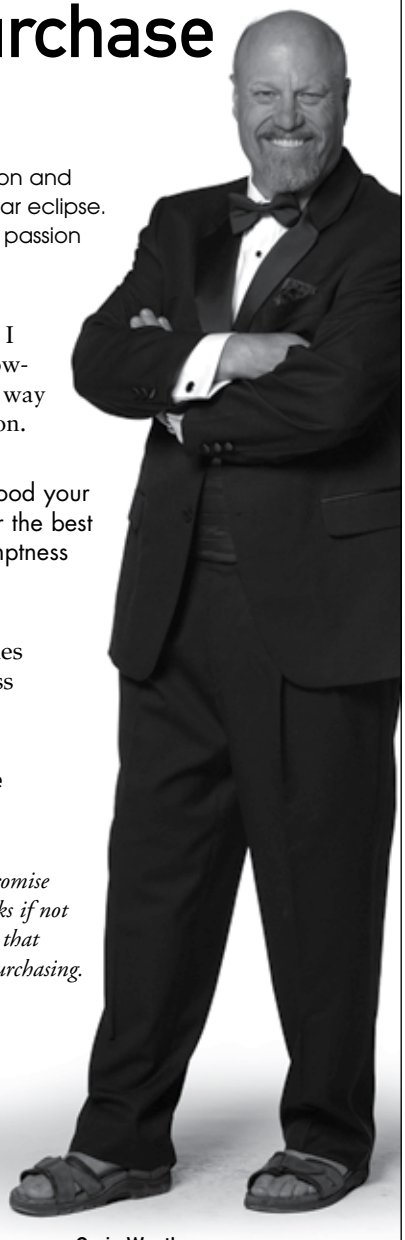

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Target these crimson beauties, and you'll be seeing red all year long. /// BY MICHAEL E. BAKICH

Tour the sky's reddest stars

Observers love red stars, and they're cool in more ways than one. First, they have the lowest surface temperatures of any stars. And second, they're great fun to look at because not many astronomical objects reveal their colors to the eye. But what makes them so red? And where do you find the reddest? This guide will help you discover some of these underobserved jewels.

Few naked-eye stars show color. The closest we come to seeing a bright red star without optics is coppery Betelgeuse (Alpha Orionis) and orange Antares (Alpha Scorpii). And while some may quibble about the reality of green stars or if a star looks purple due to a contrast effect, nearly everyone sees red well.

How red is red?

Astronomers determine a star's redness by observation and simple math. They measure the star's magnitude through blue (B) and visual (V) filters. They then subtract the visual magnitude from the blue. This leaves a number — designated B–V — called the color index. The more positive the color index, the redder the star is.

For example, if a star has a blue magnitude of 5 and a visual magnitude of 3, then B–V = 2. Color indices range from about –0.5 for the bluest stars to a bit more than 5 for the reddest. A color index of 2 makes our example a red star. The Sun's color index is 0.65.

Other color indices exist. Adding ultraviolet, red, and infrared filters gives rise to U–B (usually for hot objects), R–I (for cool objects), and other combinations. B–V, however, is the color index astronomers use most often.

Jewel in the king's crown

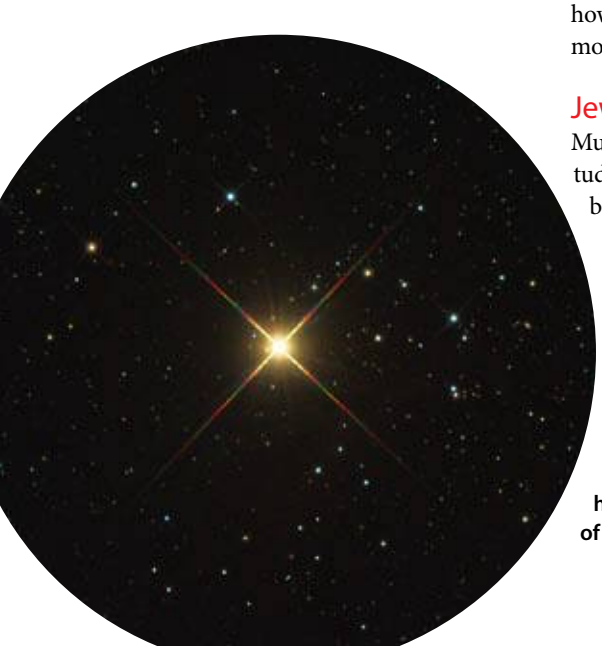
Mu (μ) Cephei sits 4.9° southeast of magnitude 2.4 Alpha Cephei. In 1783, German-born English astronomer Sir William Herschel (1738–1822) described this star as having "a very fine deep garnet colour, such as the periodical star o ceti." Later, Italian astronomer Giuseppe Piazzi (1746–1826) called it Garnet Sidus in a catalog of stars he compiled. Today, we know it as Herschel's Garnet Star.

As the prototype of a class of variable stars called Mu Cephei variables, this star swings between magnitudes 3.6 and 5 during a period of roughly 2 years. These numbers, however, give only its apparent brightness. In reality, Mu ranks as one of the brightest and largest stars known.

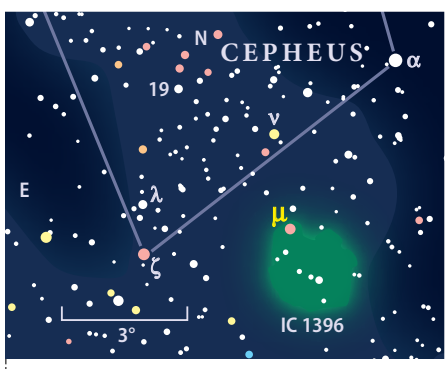
More than a billion Suns could fit inside Mu Cep, and, if it occupied our solar system's center, its outer atmosphere would lie beyond Jupiter's orbit. It outstrips the Sun's energy output by some 350,000 times. For Mu, B–V = 2.26.

Superb!

In the northern constellation Canes Venatici the Hunting Dogs, only 8° west of the famous Whirlpool Galaxy (M51), sits a variable star labeled Y. Its magnitude ranges from about 4.8 to 6.3 during a 160-day



THROUGH A TELESCOPE, Herschel's Garnet Star (Mu [μ] Cephei) will appear redder than in this image. Cameras accumulate and store light better than the human eye, so they increase the brightness of celestial images. ANTHONY AYIOMAMITIS



HERSCHEL'S GARNET STAR (Mu [μ] Cephei) sits at the northern edge of emission nebula IC 1396. Mu lies 3.6° west-northwest of Zeta (ζ) Cephei.

ALL CHARTS: *ASTRONOMY*: RICHARD TALCOTT AND ROEN KELLY

THE SKY'S REDDEST STARS, almost all of which are variable stars, deposit carbon compounds on their surfaces. As the number of dark molecules builds up, the stars become redder and fainter. *ASTRONOMY:* ROEN KELLY

period. Because Y doesn't strictly adhere to this schedule, astronomers classify it as a semi-regular variable. But what makes it famous is its color.

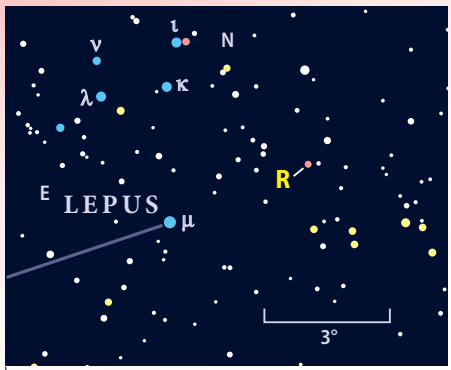
Italian astronomer Father Angelo Secchi (1818–1878), who classified a large number of stars by their spectral types, was so impressed with Y CVn that he called it "La Superba." Scientists study a star's spectrum by measuring the intensity of its light at different wavelengths.

The standard spectral classes assign letters to stars based on their temperatures. From hottest to coolest, the letters run O, B, A, F, G, K, and M. Since that system debuted, however, astronomers have classified even cooler stars. And the coolest of all are carbon stars, designated C.

Carbon stars are giants much larger than the Sun that have evolved past the point where only hydrogen fusion provides their energy. In these stars' cores, helium fuses into carbon and oxygen at much higher temperatures. Because the energy output has increased, the outer layers of these stars swell and cool, thus becoming red. But a standard red giant doesn't appear all that red because its production of oxygen is greater than that of carbon.

In carbon stars, however, carbon production outpaces that of oxygen, and carbon compounds such as carbon monoxide (CO) and cyanogen (CN) migrate to the star's surface. There, carbon molecules absorb short-wavelength light (green, blue, and violet), making the star abnormally red. In the case of La Superba, B–V = 2.55.

LA SUPERBA (Y Canum Venaticorum) lies 4.5° north-northeast of magnitude 4.2 Chara (Beta [β] CVn). La Superba is a variable star. Its brightness changes from magnitude 4.8 to 6.3.



HIND'S CRIMSON STAR (R Leporis) glows blood-red 3.5° west-northwest of Mu (μ) Leporis. For the reddest view, observe R Lep through a 6-inch or larger telescope at its faintest, magnitude 11.7.

A drop of blood

The star R Leporis in Lepus the Hare is another variable carbon star that appears intensely red. With a B–V of 2.7, R Lep rose to notoriety in October 1845, when British astronomer John Russell Hind (1823–1895) discovered it.

He found its color, "of the most intense crimson, resembling a blood-drop on the background of the sky; as regards depth of color, no other star visible in these latitudes could be compared with it." R Leporis now carries the moniker "Hind's Crimson Star" after its discoverer.

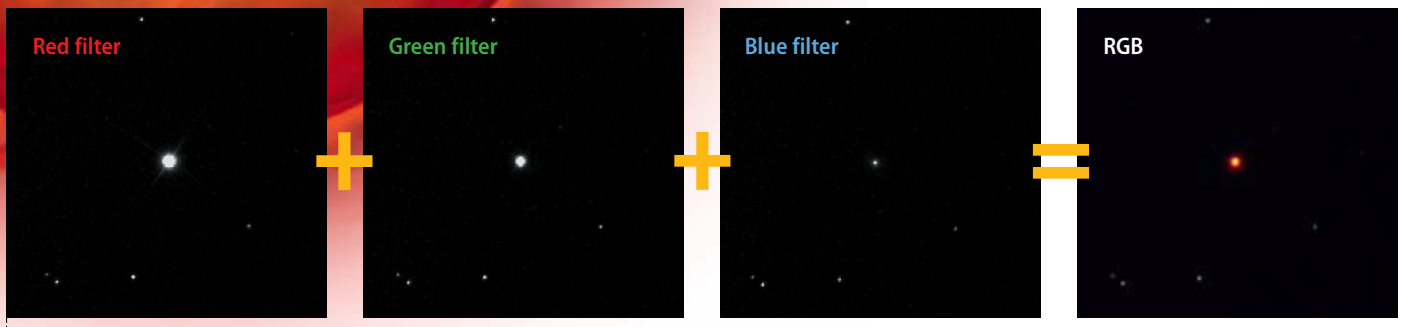
R Lep varies in brightness by more than 6 magnitudes, from 5.5 to 11.7 during a 430-day period. Because the star's atmosphere absorbs the most short-wavelength light at minimum brightness, R Lep looks reddest when faintest. That, then, is the time to observe its color. R Lep will reach minimum during autumn 2008.

Tips for observing red stars

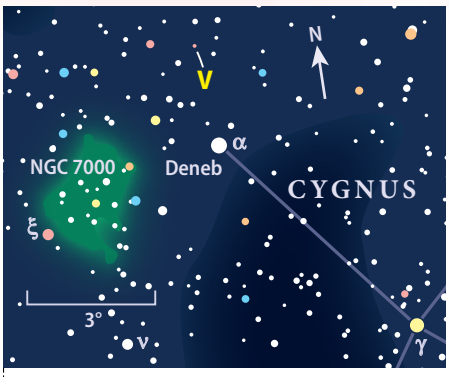
First, use your largest telescope. Your eyes require a minimum brightness to trigger their color receptors. That's why we see color during the daytime, but not at night without artificial lighting.

Center the star in your eyepiece's field of view, and ever-so-slightly defocus the image. Spreading out the star's light into a small disk will allow you to see its color

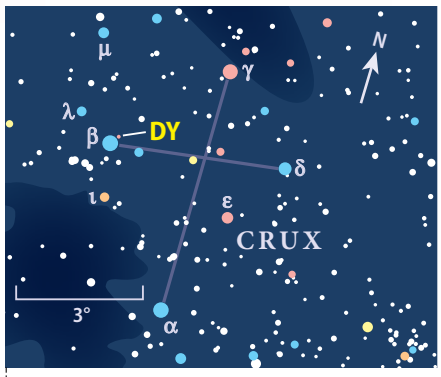
Michael E. Bakich *is a senior editor of* Astronomy.



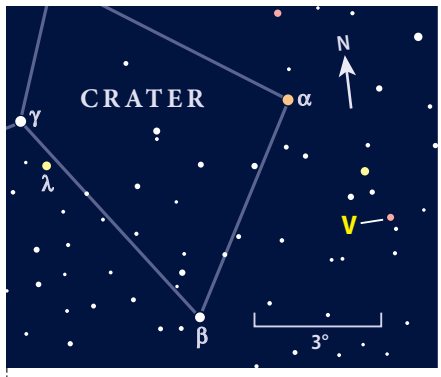
AN RGB IMAGE of R Leporis, taken with a CCD camera, shows the star appears brightest through a red filter; green and blue filters record it progressively fainter. Because R, G, and B images are monochromatic, they appear colorless. ADAM BLOCK/NOAO/AURA/NSF



V CYGNI sits 2.9° due north of Deneb (Alpha [α] Cygni), but it's not easy to find. At maximum brightness, it glows weakly at magnitude 7.8, but it fades 6 magnitudes as it moves to minimum. It will appear reddest near minimum brightness.



RUBY CRUCIS (DY Crucis) lies less than 1' northwest of magnitude 1.3 Mimosa (Beta [β] Crucis). To see 9th-magnitude DY Crucis, insert an eyepiece that gives 100x or more, and place brilliant Mimosa outside the field of view.



PERHAPS THE SKY'S reddest star is V Hydrae. It sits 3.5° south-southwest of Alkes (Alpha [α] Crateris). At maximum brightness, V Hya hovers near naked-eye visibility at magnitude 6.5, but it drops to magnitude 12 during a 533-day period.

better. Be aware that your scope's optics may not be perfectly aligned. First, adjust the focus so the eyepiece moves inward. Then, move past the focus point an equal amount in the other direction. View whichever disk looks rounder.

If possible, observe these targets when they're on or as close to the meridian (the imaginary line passing north to south through the overhead point) as possible. A star on the meridian sits highest in the sky. Viewing any star at other than its maximum altitude introduces false reddening from our atmosphere, like the Sun's changing color at sunrise and sunset. Believe me, you won't need the help.

A CCD CAMERA attached to a small telescope easily captures the variable star V Cygni at minimum brightness. Stars like V Cyg appear reddest at minimum brightness. V Cyg has a color index of 4. ANTHONY AYIOMAMITIS

Author picks

Along with the three famous stars above, lots of other deep-red stars populate the sky. Here are some of my favorites:

• V Cygni may be tough to observe at minimum, but its color index of 4 makes the effort worthwhile. During its 420-day period, this star drops 6 magnitudes, from 7.8 to 13.8. Luckily, even at maximum brightness, you'll see a lot of red. Find this star 2.9° north of Deneb.

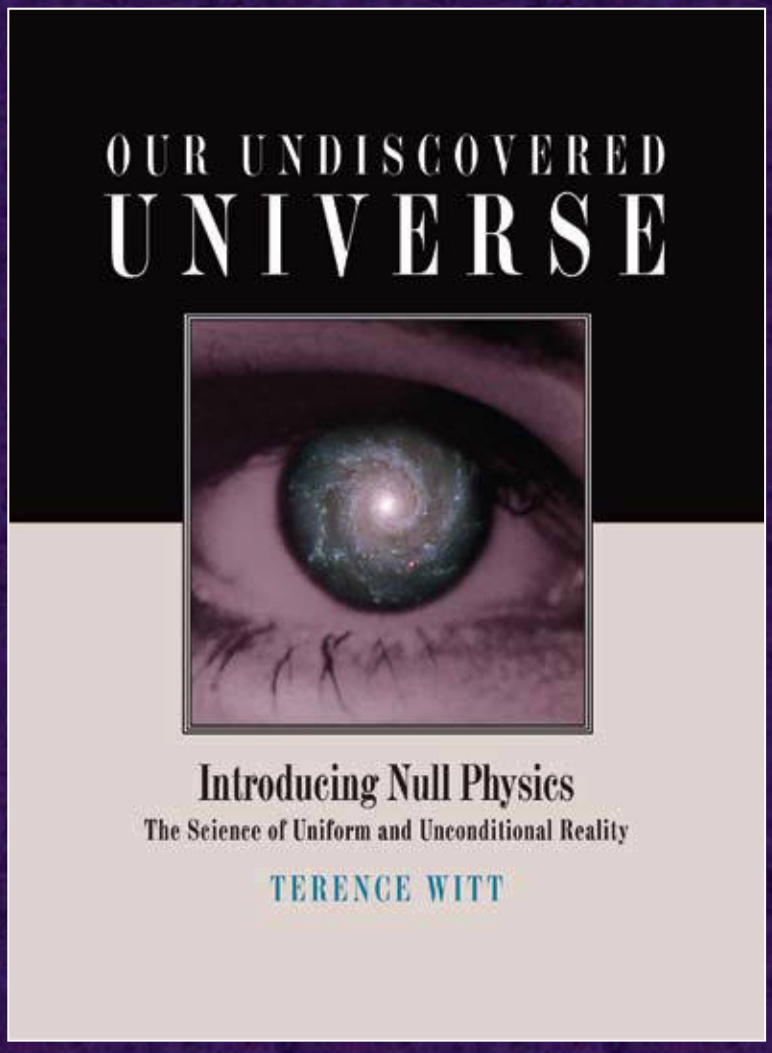
• Southern Hemisphere observers should look for DY Crucis, also known as Ruby Crucis — a well-deserved name considering its B–V of 5.56. This star varies in brightness from magnitude 8.6 to 9.8 and lies quite close to Mimosa (Beta Crucis). For the best view, move magnitude 1.3 Mimosa out of your eyepiece's field of view.

• V Hydrae — Observers consider this the reddest of all stars when its brightness lies at minimum, and with a B–V of 5.5, I can't disagree. V Hydrae's magnitude varies between 6.5 and 12 during a 533-day period. V Hya sits in central Hydra near its border with Crater the Cup. Observe it in early May when it lies near the meridian an hour after sunset. On star maps, don't confuse it with Nu (ν) Hydrae, which lies 5° north. The Greek letter Nu looks like a V.

You want more?

The Saguaro Astronomy Club (SAC) of Phoenix maintains a number of great observing databases, one of which contains 333 red stars. Go to www.saguaroastro.org/content/downloads.htm, and click the "SAC red stars database" to download it.

Red stars will please your eyes and help you refine your telescope skills. If you keep an observing log, you may exhaust your thesaurus searching for other ways to say "red." One thing's for sure, though. Looking at these stars won't give you the blues.



Physicists sometimes wonder if a new theory might emerge that makes quarks, the Big Bang, and superstrings completely obsolete.

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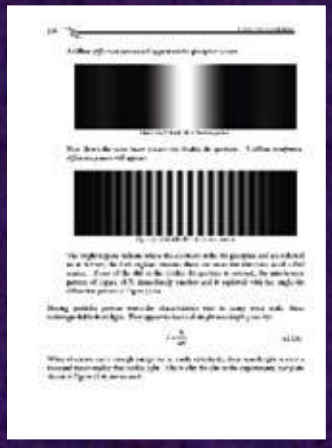

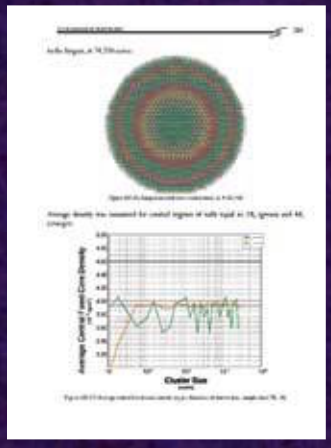

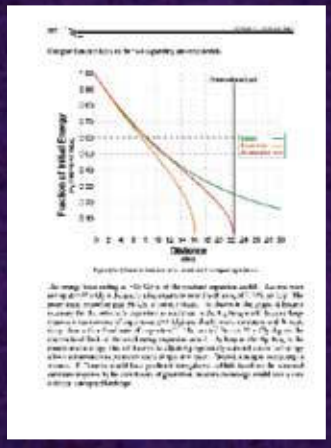

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ONLINE

With a fresh style and new features, *Astronomy*'s web site covers the science and hobby of astronomy like no other. /// **BY LAURA BAIRD**

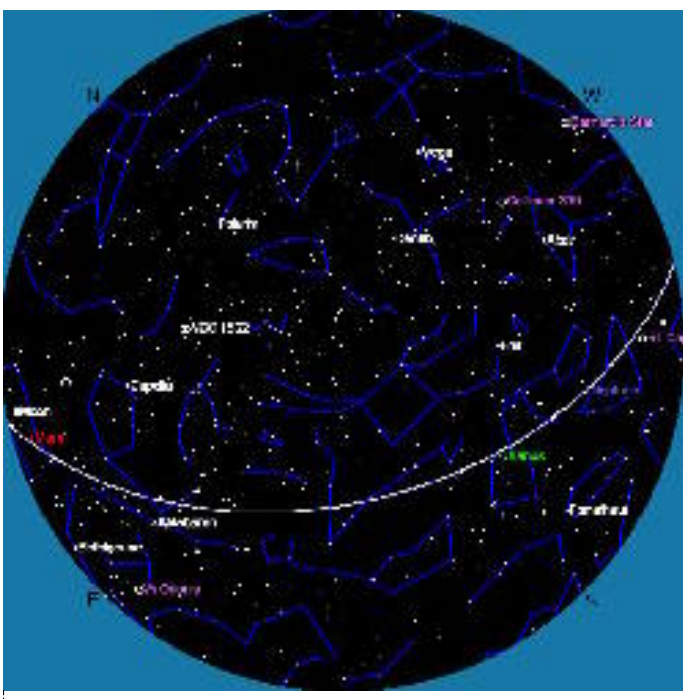
Astronomy.com gets an extreme makeover

Astronomy's web site presents a new look — and more. We're adding features that will make it easier than ever to stay connected with the hobby and science of astronomy. When the new Astronomy.com goes "live" in late November, it will deliver more of what you told us you wanted: breaking news, information on what planets and deep-sky objects are in your sky tonight, and more videos, podcasts, and downloadable desktop wallpaper.

What's up?

The site's crown jewels are its new daily almanac, Tonight's Sky; custom StarDome; and interactive Star Atlas. Whether you want to know what planet you saw glowing in the twilight or you're planning a hardcore, all-night observing session of deep-sky gems, these three tools together will provide all the information you need.

At a glance, Tonight's Sky tells you the Moon's phase and when naked-eye planets are visible. The sky-event ticker alerts you to must-see sky events like meteor showers, comets, or rare planetary conjunctions. If you have only a minute to observe the sky, check here first.



THE NEW STARDOME maps the sky overhead from any place at any time. StarDome Plus offers extra features for magazine subscribers.

If you want more detail, StarDome and StarDome Plus plot the night sky as seen from any location on Earth at any time of day. The new StarDome displays a circular all-sky map or horizon view with 2,600 stars down to magnitude 5.5. It also shows the planets, naked-eye comets, the Moon, and all the Messier objects.

An exclusive benefit for *Astronomy* magazine subscribers, StarDome Plus displays comets and asteroids, 9,300 stars — down to magnitude 6.5 — and detailed observing reports for 800 deep-sky objects.

"Additional functions in StarDome Plus show the planets' orbits, the motions of Jupiter and Saturn's moons, eclipse paths, a calendar, and tables of positions for sky objects," says Senior Editor Francis Reddy. This multifaceted tool places the universe on your desktop.

Another great perk of your magazine subscription is exclusive access to the interactive Star Atlas. This is an online version of *Astronomy*'s popular *Atlas of the stars*, with the added capability to zoom in on the 24 overlapping maps. This handy reference plots 45,000 stars down to 8th magnitude, and accompanying text highlights the best objects to observe on each map.

A fresh take

You'll also notice the site's new color scheme, layout, and organization. "Now it's easier to find what you're looking for — and to connect with the magazine staff and other amateur astronomers," says Assistant Editor Jeremy McGovern.

Get to know our editors in the blog, podcast, and videos. The *Astronomy* staff gives you the freshest take on astronomy in the news, and brings you interviews with leading scientists and authors. Videos highlight the latest equipment and give you great how-to hobby tips, like Senior Editor Michael Bakich on how to observe a meteor shower or Editor Dave Eicher on how to sketch celestial objects at the eyepiece.

The new Community pages bring together forums, a calendar of events, and

Laura Baird *is an associate editor of* Astronomy.

A NEW LOOK complements the new features added to Astronomy.com. Get your science news, observing tools, and entertainment in one convenient place.

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The weekly podcast brings you exclusive interviews on major discoveries, astronomy history, books, and sky events.

"Astronomy Plus" indicates material restricted to magazine subscribers only. Benefits include these highlighted features and more.

Cast your vote in the weekly poll, and see how others have responded.

Tonight's Sky displays Sun and Moon rise and set times, the lunar phase, when and where to see the naked-eye planets, and upcoming sky events — all at a glance.

The new navigation bar makes it easy to explore the site.

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astronomy group listings. So, you'll have all the resources you need whether you want to ask an astrophotography question in the forums or find out when a local club meets.

Something for everyone

Don't worry — despite these great additions, we've kept all your old favorites: news, astronomy for kids, picture of the day, new product showcase, and the weekly online poll, to name a few.

If you're new to the hobby, the Welcome to Astronomy page has everything you'll need to get started. Learn about the constellations and planets, as well as what to look for when choosing binoculars or a telescope. All of these articles are freely accessible and will show you how simple it is to start observing tonight.

We've also made it easier for readers to take advantage of all the perks their magazine subscription affords. Subscriber extras include access to popular magazine columns like "The Sky this Month," "Ask Astro," and "Stephen James O'Meara's Secret Sky."

Plus, monthly web extras take you beyond the magazine's printed pages. These features bring you additional research, interviews, and photographs our editors turned up while creating the stories you find in the magazine. You'll uncover amazing animations, and much more that didn't, or couldn't, make it into print.

While you're checking out all the new observing tools and information on Astronomy.com, take a second to sign up for *Astronomy*'s weekly newsletter. Just enter your e-mail address, and you'll receive the week's hottest news, images, and sky-event notices right in your inbox.

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ASK ASTRO

This month:
- Does redshift increase over time?
- How do gravity assists work?
- Why do planets in our solar system orbit in the same plane?
- Does the "green flash" ever occur during sunrise?

CHANGING REDSHIFT

Q: Does redshift increase over time? — **R. SCHULTZ,** CHESTER, OHIO

A: Yes, it does. Many people think of redshift as due to a Doppler effect from a distant galaxy's "recession velocity." In fact, it is more accurate to think of a photon's wavelength as being stretched by the expansion of space. As the universe expands, a galaxy's redshift increases (photons become redder as their wavelength gets longer).

Current observational evidence indicates the universe will continue to expand. However, the universe might contain too much matter and, thus, too much gravity for expansion to continue indefinitely. In this case, the universe ultimately will contract. This scenario would result in a blueshift. Photon wavelengths would get shorter as the universe contracts and galaxies crowd closer together. — **SIMON DEDEO,** KAVLI INSTITUTE FOR COSMOLOGICAL PHYSICS, UNIVERSITY OF CHICAGO

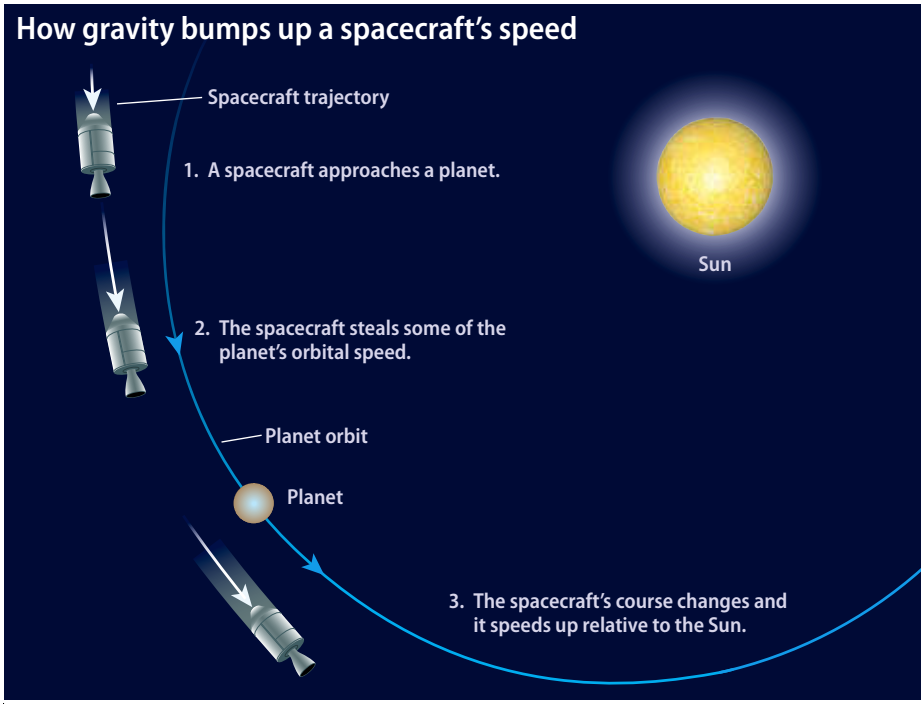
GRAVITY ASSIST

Q: How do gravity assists work? — **ALEX FORBES,** CASTRO VALLEY, CALIFORNIA

A: By passing near a large body, a spacecraft can radically alter its speed and trajectory without expending any fuel. This may sound like a free lunch, but it isn't.

A spacecraft that speeds up during a gravity assist does so by taking away some of the planet's orbital energy. An imperceptible slowing of the planet results in a vast speed boost for a spacecraft. Mission designers also can select trajectories that slow a spacecraft or alter its orbital inclination.

In 1961, Michael Minovitch, a mathematics and physics graduate student working during the summer at the Jet Propulsion Laboratory in Pasadena, California, discovered this technique. It was first employed in February 1974, when NASA's Mariner 10 mission to Mercury used Venus to alter the craft's course and speed. — **FRANCIS REDDY,** SENIOR EDITOR


How gravity bumps up a spacecraft's speed
Spacecraft trajectory
1. A spacecraft approaches a planet.
Sun
2. The spacecraft steals some of the planet's orbital speed.
Planet orbit
Planet
3. The spacecraft's course changes and it speeds up relative to the Sun.

A GRAVITY ASSIST boosts a spacecraft by taking away orbital energy from a moon or planet. Different trajectories can slow a spacecraft into orbit (as with Galileo in 1995) or radically alter a probe's orbital inclination (like Ulysses, February 1992). *ASTRONOMY:* THEO COBB

ORBITAL PLANE

Q: Why do all planets in our solar system orbit in approximately the same plane? — **RILEY LARKINS,** MANCHESTER, NEW HAMPSHIRE

A: The fact that all the planets in our solar system orbit in the same direction about the Sun, on nearly circular orbits, and in the same plane (to within a few degrees, with the exception of Mercury) was known to astronomers hundreds of years ago. This fact led Immanuel Kant in 1755 and Pierre Simon de Laplace in 1796 to hypothesize that **the solar system's planets formed out of a rotating disk of gas and dust.**

Such a disk would naturally explain planetary orbits, and 18th-century astronomers believed the "nebulae" discovered by William Herschel were examples of new solar systems being formed. We now know that Herschel's nebulae were actually spiral galaxies; however, astronomers have discovered and imaged examples of solar systems in the making, such as the disk in orbit around the young star HH30. — **ALAN BOSS,** CARNEGIE INSTITUTION OF WASHINGTON

GREEN FLASH

Q: Does the "green flash" ever occur during sunrise, or is sunset the only time one can occur? — **JOHN LOCKWOOD,** WASHINGTON

A: Green flashes — when part of the Sun suddenly changes color from red or orange to green — occur at sunrise as often as sunset. Observers see most green flashes at sunset because it's easier to find the precise location of sunset than sunrise — just follow the Sun's disk until it sets. (Use a solar filter until just before the Sun disappears.)

Two factors determine a green flash's visibility: First, you need a low, distant horizon. Enough air must lie between your eyes and the Sun to make a "lens" to bend the sunlight. For this reason, most green flashes appear over water.

The second factor is sky transparency. If the Sun appears bright when it lies two solar diameters above the horizon, you stand a chance of seeing the flash.

Sunrise has an advantage. Because no atmospheric heating occurs at night, clear mornings generally have better transparency than clear evenings. So, if you know just where to look, odds are better for a morning green flash. — **MICHAEL E. BAKICH,** SENIOR EDITOR

COMING NEXT MONTH ...

What causes comets' strange orbits? Post your comments about this question online at www.astronomy.com/forums.

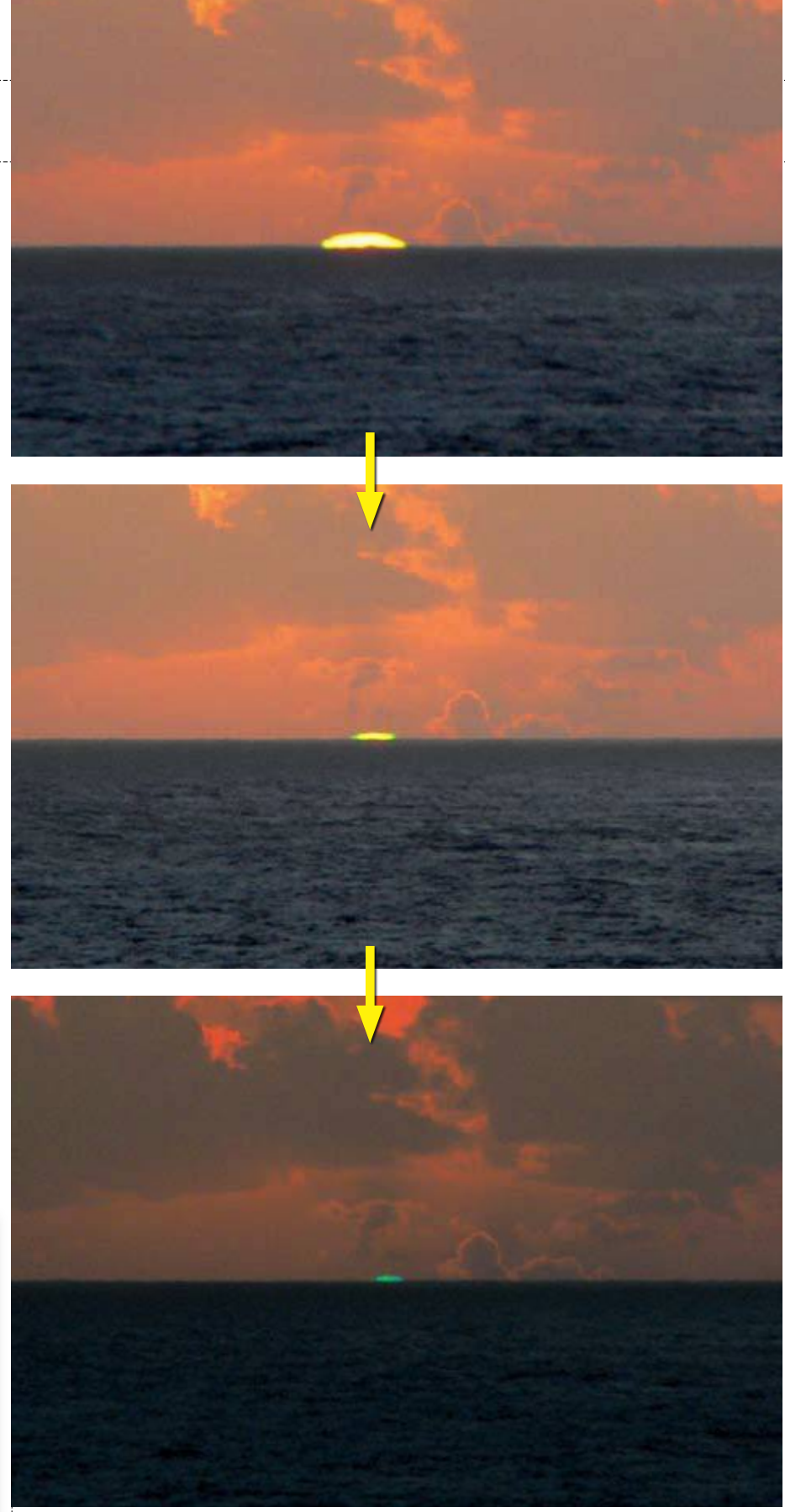
Send your questions via e-mail to: askastro@astronomy.com; or write to: Ask Astro, P. O. Box 1612, Waukesha, WI 53187. Be sure to tell us your full name and where you live. Unfortunately, we cannot answer all questions submitted.

IN THE KNOW

DOPPLER EFFECT
The radiation wavelength change coming from light's moving toward or away from an observer.

REDSHIFT
Wavelength increase coming from an object's motion away from an observer, the expansion of the universe, or a strong gravitational field.

BLUESHIFT
A decrease in light's wavelength coming from motion toward an observer or the contraction of the universe.



THE GREEN FLASH is a rare and fleeting phenomenon that occurs during sunrise's first moments or, as seen in the sequence above, during sunset's last moments. Amateur astrophotographer Paul Hider captured this green flash aboard a ship sailing in the Pacific Ocean north of Pitcairn Island.

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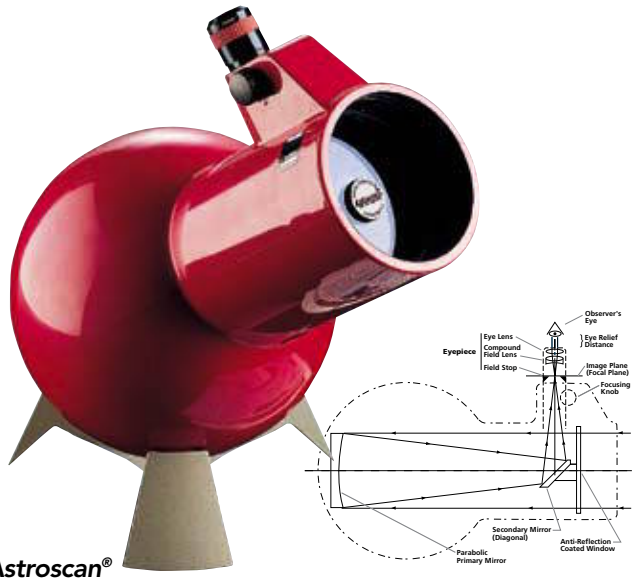

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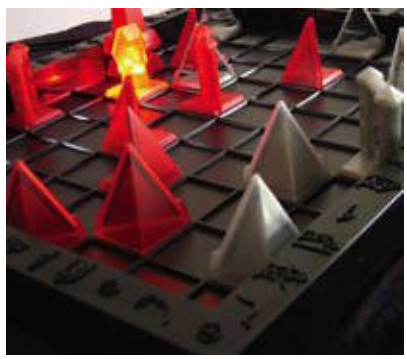

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Don't miss the Red Planet this December because it won't look any better until 2016. /// **BY MICHAEL E. BAKICH**

15 tips for observing Mars

Christmas comes early for amateur

astronomers this year as Mars once again dominates the evening sky. Dust off your telescope because now's the time to form your observing strategy. To help you target Mars, I've developed this list of helpful tips.

1 Target December 24

For those readers new to Mars mania, astronomers' excitement peaks during times called oppositions, when Mars lies opposite the Sun. This year's opposition occurs December 24. On that date, Mars appears fully illuminated.

An opposition happens every 780 days (minus 1 hour 26 minutes 24 seconds, to be exact). But each closest approach to Earth by Mars is not really, well, closest. The reason is the orbits of Earth and Mars are not circular. During a distant opposition, Mars can be more than 60 million miles (97 million km) away. Contrast that with a nearby opposition that places Mars less than 35 million miles (56 million km) from Earth.

2 Know the numbers ▶

It all comes down to apparent diameter. Astronomers use angular measurement to describe how large a celestial object appears. A planet's angular size can change a lot. Mars varies in size at opposition from 13.8" to 25.1". And its brightness varies from magnitude –1.5 to –2.9.

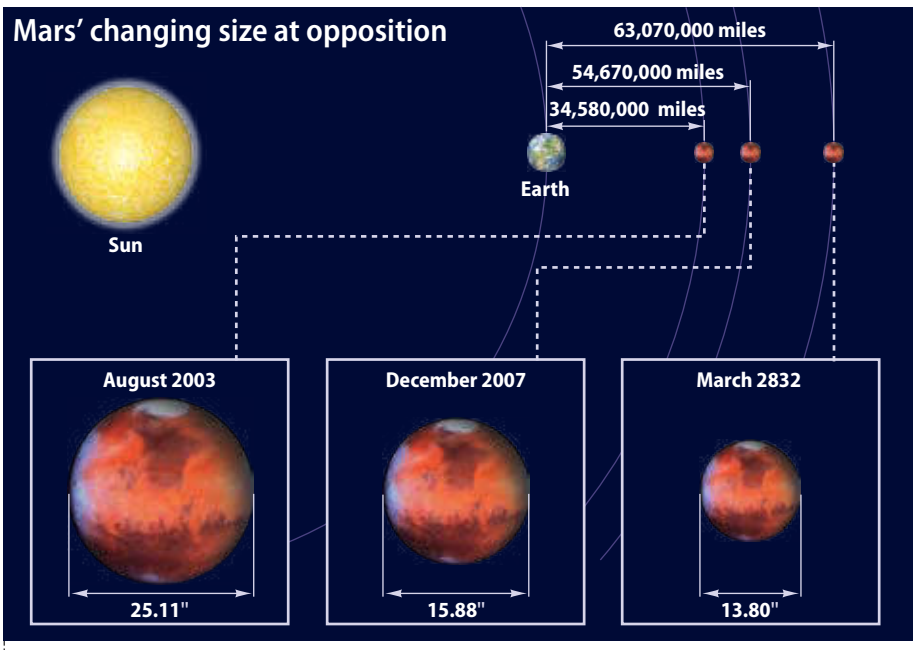
In 2007, opposition occurs on the 24th, but Mars lies closest to Earth (and thus appears largest) on the 18th. The Red Planet will lie 54,670,000 miles (88,170,000 km) away then. It will span 15.9" and shine at magnitude –1.6.

3 Beware the myth!

"Mars will look as large as the Full Moon to the naked eye." This statement first appeared in an e-mail during mid-2003, then again before Mars' opposition in 2005. Nothing could be further from the truth, but you should expect to see it again this year. Just tell your friends it's someone's idea of an Internet joke.

4 Head south

At opposition this year, Mars' declination (distance above or below the celestial equator) will measure 26°46'. For an observer



ALTHOUGH SMALLER and farther away than at its best in 2003, Mars in 2007 will appear larger than during its worst opposition, 8 centuries from now. *ASTRONOMY:* ROEN KELLY

Michael E. Bakich *is a senior editor of* Astronomy.

THIS GLOBAL VIEW of Mars is a legacy of the Viking 1 orbiter. South is up, which mimics the view through a telescope. The white north polar cap sits at the bottom, the Valles Marineris canyon system lies above center, and four huge Tharsis volcanoes appear at right. USGS

located at 40° north latitude, Mars will climb 77° above the southern horizon at midnight. It's important to consider a planet's altitude because the less air you view through, the better the image. So, if you have a choice, head south.

5 Pick your site carefully

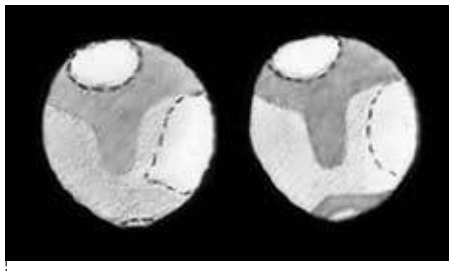
Mars is so bright that the darkness of your site doesn't matter much. Even under urban skies, you'll easily see details through small telescopes. What will make a difference is the steadiness of the air above your site, which contributes to good seeing. The better the seeing, the more detail your scope will reveal.

6 Watch Mars move ▼

During November, Mars lies in Gemini. On the 1st, it shines at magnitude –0.6, brighter than all stars except Sirius (Alpha [α] Canis Majoris) and Canopus (Alpha Carinae). Mars brightens until December 24, then begins a slow fade. It crosses into Taurus on the 30th and remains there through January. When January ends, Mars once again glows at magnitude –0.6. During these 3 months, the Red Planet moves 18°.

7 Don't wait for opposition ▼

Although Mars will be biggest and brightest around opposition, you can make quality observations for several months before and after that date. In both early November and late January, Mars will measure 12" across, 75 percent of its maximum size this year. As long as Mars' atmosphere is transparent (no dust storms), detail will be visible.



YOU CAN STILL SEE martian detail when the planet appears small. This pair of sketches from February 14, 2001, shows Mars when its apparent size was only 6.93". The large, dark albedo feature is Syrtis Major. DAMIAN PEACH

8 Target Syrtis Major

With the possible exception of the Red Planet's polar ice caps, the easiest martian feature for observers to identify is the dark triangular albedo feature named Syrtis Major. Once you've found it, monitor it occasionally for changes. When I first started observing Mars, Syrtis Major noticeably grew and then shrank as the martian summer passed. For the last decade, though, it's been quite constant.

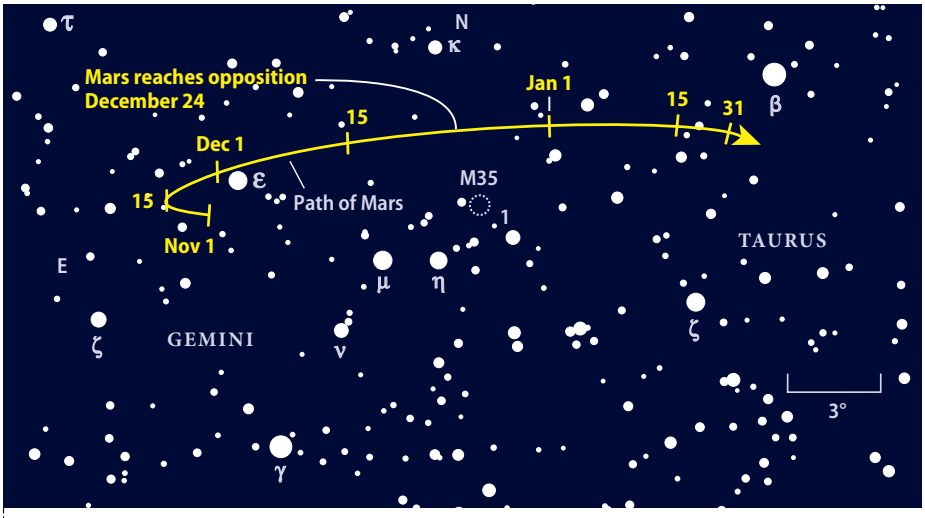
MANY DETAILS are apparent in this color sketch of Mars made May 22, 2001. The imager used a 12-inch telescope and combined an unfiltered view and one through a #25 red filter to capture Mars when its apparent size was 17.77". DAMIAN PEACH

9 Learn Mars' major features ▲

Through a 4-inch or larger telescope, you can observe large albedo features — regions distinguished by the amount of light they reflect. Mars' best albedo features include Syrtis Major, Chryse, Elysium, the Hellas Basin, Libya, and Solis Lacus. Albedo features are the areas most subject to seasonal changes such as brightening or darkening.

10 Track martian longitude ▼

Mars' day (which astronomers call a sol) is 37.4 minutes longer than an Earth day. So, if you observe Mars at the same time each night, its markings will appear to move 9.11° per day to the west. In a little more than 5 weeks, the planet seems to slowly rotate backward one full spin. All of Mars' prominent features would, at some time during this period, lie on its meridian, the line splitting Mars' visible disk from top to bottom.



THE RED PLANET soars high in the sky for northern observers late this year as it reaches opposition among the stars of Gemini. *ASTRONOMY:* ROEN KELLY

THESE FOUR IMAGES, taken by the Hubble Space Telescope near the planet's 2001 opposition, show many albedo features. S. LEE (UNIV. OF COLORADO)/J. BELL (CORNELL UNIV.)/M. WOLFF (SPACE SCIENCE INSTITUTE)/NASA

MARS MEASURED 9.1" at the time of this image, 4h59m UT on June 27, 2005. Several large albedo features and the bright south polar cap are visible. RALF VANDEBERGH

11 Don't miss the ice caps ▲

The Red Planet's most prominent surface features are its polar ice caps. Due to the temperature range, astronomers subdivide each ice cap into larger "seasonal" and smaller "residual" caps.

The southern residual ice cap measures approximately 200 miles (320 km) across. The northern residual ice cap spans about 600 miles (960 km).

Winters are more severe in Mars' northern hemisphere, and the seasonal ice cap there has reached a latitude of 45°. In the southern hemisphere, the seasonal ice cap never passes above a latitude of about –55°.

Don't confuse Hellas with the polar cap. Hellas is a round, bright feature — an impact basin with lots of bright dust and sometimes fog or clouds. When seen near the limb, it can look like a polar cap.

12 Understand cloud types

All martian clouds are temporary. Discrete clouds associate with a specific area, and Mars' rotation carries them along.

Orographic clouds are a type of discrete cloud. Wind passing over high martian mountains and volcanoes creates these water-vapor clouds. Observe orographic clouds through a blue or violet filter to see the most contrast.

Move away from Mars' central meridian, and observe morning and evening clouds. These bright, isolated patches of surface fog appear at sunrise (the western edge of Mars) and sunset.

Evening clouds generally appear larger and more numerous, and, as the martian night approaches, they grow larger. These clouds respond best to blue or violet filters.

13 Know what filters do

Many amateur astronomers dislike color filters for two reasons: They don't know what the filter should show, and they find the view unappealing. Despite their name, color filters don't show changes in color. Rather, they show brightness changes.

Filters enhance hard-to-see details on Mars by increasing or reducing contrast between features. Filters amplify subtle differences between adjacent regions by transmitting (keeping visible) one color while absorbing (blocking) others.

Because Mars is predominantly red, a red filter accentuates the planet's ruddy deserts, while darkening its greenish regions. Viewing Mars through a green filter produces the opposite effect.

Color filters show a lot when you observe Mars, but they do take some getting used to. Be patient, and you'll be amazed at how much more detail you'll see.

14 Watch for dust ▼

Mars is famous for dust storms. However, these temporary phenomena appear interesting only when they are localized — associated with a specific desert region — not global dust storms that blanket Mars' surface. Dust storms occur more often when Mars lies closest to the Sun and the heating is greatest, but they can pop up anytime. Because Mars' 2007 perihelion isn't one of its closest, astronomers don't expect a global dust storm.

15 Be patient

Although Mars will appear brightest December 24, it will look almost as bright several weeks before and after that. So, if you're clouded out, or if Christmas Eve just doesn't work for observing, cheer up. A martian opposition isn't a short-lived event, like totality during a solar eclipse. You'll have plenty of time to view Mars at its best. A

MARS ON THE INTERNET

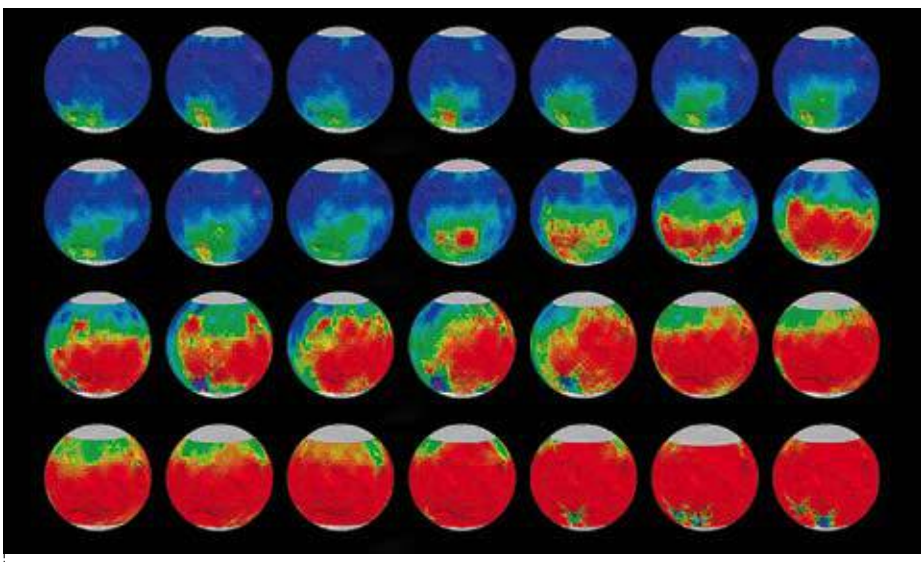
Several great web sites exist for Mars observers. Check out these three:

Dave Klassen's International Marswatch web site at elvis.rowan.edu/marswatch summarizes dust activity and other occurrences. Also, astrophotographers can upload images there.

The Oriental Astronomical Association's CMO site is at www.mars.dti.ne.jp/~cmo/oaa_mars.html. Despite the name, it's in English and lists Mars news.

Planetary observer Jeff Beish maintains a Mars site at www.tnni.net/~dustymars. It's loaded with techniques, apparition data, and free downloads of Beish's ephemeris programs. — *M. E. B.*

WEB EXTRA For 10 additional Mars observing tips, visit www.Astronomy.com/toc.



A PLANET-WIDE DUST STORM gripped Mars after its perihelion (closest approach to the Sun) in 2001. These observations from the orbiting Mars Global Surveyor (MGS) spacecraft illustrate the storm's progress as measured by the Thermal Emission Spectrometer, which can determine both temperature and the amount of atmospheric dust. Blue represents relatively clear atmosphere, and red indicates increasing dust. TES TEAM/MGS/JPL/NASA

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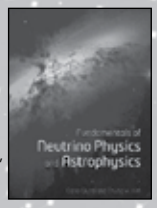

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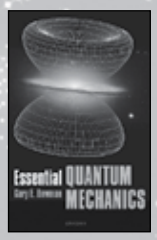

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What's your favorite place to observe? *Astronomy* asked amateurs to reveal their best sites. /// **BY DANIEL PENDICK**

Stargazers' sweet spots

On dark, clear evenings, astronomical observers head out to select, dark locations — deep in the forests of western Massachusetts, perched on mountains in Hawaii and California, or in remote corners of the Everglades — where other people with a similar interest in looking at astronomical objects gather. We asked amateur astronomers to reveal their most treasured places for stargazing. Here is a smattering of prime sites from across the continent.

Mauna Kea Visitor Information Station

The Mauna Kea Visitor Information Station, 9,200 feet (2,800 meters) above the Pacific Ocean, is only an hour's drive from Hilo, the large town on the east coast of Hawaii's Big Island. Station staff and volunteers conduct free stargazing sessions from 6 to 10 P.M. daily. Individuals can bring telescopes to the site at night; groups should submit a "special request" form (available on the station's web site).

If you intend to stargaze at the station at night, be sure to tell the rangers and guides what you have in mind. The public restrooms are open 24 hours a day.

Mount Pinos

Air and light pollution have slammed the lid on urban Los Angeles for astronomical viewing. To find the remedy, just hop on Interstate 5 and drive north to Mount Pinos. It's about 60 miles (96 kilometers) northwest of Los Angeles in the Los Padres National Forest. Depending on traffic conditions, it will take you 1½ to 2 hours to reach the site.

When you arrive at Los Padres, head for the Mount Pinos campground. After you pass the campground and reach the end of the road, you'll find a paved parking area. On Saturdays during New Moon, the site fills up quickly. It's wise to show up before dark to secure a parking spot and also to avoid ruining astrophotos-in-progress.

At the parking lot and nearby campgrounds, you'll find outhouses but no flush toilets. It can get cold at night, so bring warm clothes. People observe at Mount Pinos primarily from May to October.

Edmund G. Kline Dark Site

In 2002, the Denver Astronomical Society (DAS) leased a private dark site east of Deer Trail, Colorado, about 60 miles (96 km) from downtown Denver. After the death of longtime member Ed Kline, the DAS renamed it the Edmund G. Kline Dark Site.

The dark site's amenities include 14 concrete telescope pads with AC power outlets and three imaging and research pads. Comforts for observers include a vault toilet with nighttime red lighting and a warming hut with electric heat, red lighting, a microwave oven, and seating. Although the site is nominally for the private use of DAS members, individual observers, groups, and school classes can arrange for a special visit.

Anderson Mesa

A dark jewel of the Southwest lies just 12 miles (19 km) southeast of Flagstaff: Anderson Mesa. The Mesa hosts Lowell Observatory's research telescopes in several domes amidst the trees. It's a rural site — no toilets or running water available — but

FOR MORE INFORMATION

Anderson Mesa
See the information page on Belt of Venus, the web site of Flagstaff amateur observer Jeremy Perez: www.perezmedia.net/beltofvenus/archives/000675.html.

Arunah Hill Natural Science Center
Contact Ed Faits directly (efaits@comcast.net). You can also join the center via its web site for $20. For detailed information about the center, see www.arunah.org.

Edmund G. Kline Dark Site
Go to www.denverastrosociety.org/dss.html. Visitors who wish to visit the EGKDS should e-mail one of the DAS officers or Executive Board members. The link can be found on the DAS web site: www.denverastrosociety.org.

Mahogany Hammock Trail
For information, see the web site: www.nps.gov/ever/planyourvisit/mahogany-hammock-trail.htm.

Mauna Kea Visitor Information Station
Call 808.961.2180 or visit the station web site: www.ifa.hawaii.edu/info/vis.

Mount Pinos
Consult the Los Padres National Forest web site: www.fs.fed.us/r5/lospadres. Also, see the "First-Timer's Guide" to Mount Pinos observing at www.lgscv.org. To find the guide, click the site's "Search" button and type in "Mount Pinos." The guide includes detailed driving directions and important information on weather conditions.

Daniel Pendick *is an associate editor of* Astronomy.

it offers spectacularly dark skies to rival any in the Southwest.

The roads in the area are dirt and sometimes rough, so be careful driving at night. And don't forget to arrive at the Mesa before dark. Driving into the area with headlights blazing will upset amateur astronomers who may already be there.

Arunah Hill Natural Science Center

The Arunah Hill Natural Science Center is in western Massachusetts, amidst the forested hills between Northampton and Pittsfield. This rural site hosts a small observatory equipped with the center's historic 6¼-inch Brashear-Gaertner refractor. Also available to visitors are a 13-inch Fitz-Clark refractor and 18- and 24-inch Dobsonian-mounted reflectors. "It is about 2,005 feet high, very accessible, and with great views of the Milky Way in the summer viewing season," says Jim Zebrowski, president of the Aldrich (Massachusetts) Astronomical Society. The site has two outhouses but no running water or flush toilets.

Except during public events, the Arunah Hill Natural Science Center is for the use of dues-paying members. Edward Faits, the center's president, says guests are welcome if escorted by members. People observe at Arunah just about every clear moonless weekend night, May to November.

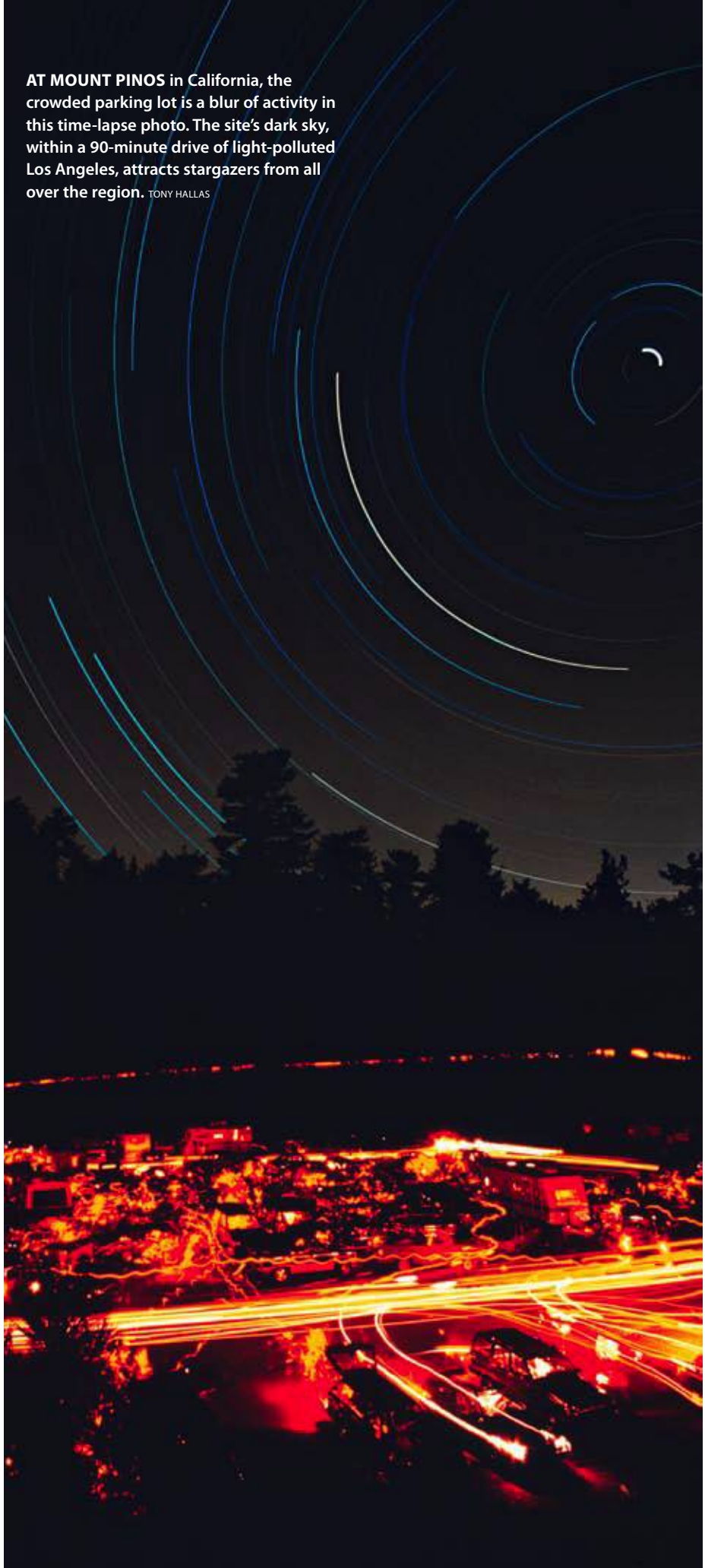
Mahogany Hammock Trail

At the Mahogany Hammock Trail, a secluded spot in Everglades National Park about 20 miles (32 km) west of Homestead, Florida, you can explore a unique subtropical hardwood-tree ecosystem. Then, when the Sun sets, you can observe the sky.

In the mid-1980s, the Southern Cross Astronomical Society held its celebrated Winter Star Party at Mahogany Hammock. The party has since moved to the Florida Keys, but Mahogany Hammock is still a fine dark site within comfortable driving distance of Miami.

You are free to observe at the Mahogany Hammock site 24/7. However, it has no restrooms or running water. And keep in mind the site is open to non-observers, too. Be prepared for sudden blasts of automobile headlights at any time.

WEB EXTRA View photos of the sites featured and share your sweet spot at www.Astronomy.com/toc.



AT MOUNT PINOS in California, the crowded parking lot is a blur of activity in this time-lapse photo. The site's dark sky, within a 90-minute drive of light-polluted Los Angeles, attracts stargazers from all over the region. TONY HALLAS

Vixen's computerized mount is lightweight, sturdy, and easy to use.

/// BY PHIL HARRINGTON

The Skypod mount performs superbly

Vixen Optical has come close to designing the perfect grab-and-go telescope mount — the Skypod — run by the innovative Starbook computerized control system. The Starbook debuted to rave reviews as part of Vixen's state-of-the-art Sphinx German equatorial mount

a couple of years ago. More recently, Vixen coupled a downsized version called the Starbook S to an alt-azimuth mount to create the Skypod. Once set up and initialized, the Skypod mount will aim a telescope toward any of more than 22,000 objects in the Starbook's memory and then track that object across the sky.

Two sets of five buttons work all of the functions. The Starbook control box and its 46-inch connecting cable slide neatly into the mount for storage and transport. You can also detach the Starbook from the Skypod mount and use it as a pocket planetarium. Rather than a small display with text crawling along a readout, like most go-to telescopes, the Starbook includes an LCD screen that displays the night sky for the exact day and hour the user chooses.

Setting up the Skypod is simple: Attach the fully assembled mount to the aluminum tripod using a captive thumbscrew. The Skypod's internally geared motors run on 8 AA batteries. The Starbook controller relies on its own set of 4 AA batteries.

Adding optics

Vixen offers the Skypod/Starbook combo with a choice of 70mm or 80mm refractors, a 130mm Newtonian reflector, or the unique 4.3-inch f/9.4 VMC110L telescope reviewed here. Vixen bills the VMC110L as a "modified Cassegrain." A better description may be a takeoff on the Klevtsov-Cassegrain catadioptric design. Most traditional catadioptrics rely on a front corrector plate to pre-bend light entering the optical system so it comes to a sharp focus by the time it bounces off the internal mirrors and through the eyepiece. The VMC110L eliminates the corrector plate, using instead a small corrector lens just ahead of the secondary mirror.

Because there's no corrector plate, a curved-vane spider mount supports the VMC110L's secondary mirror. The vanes are thick, however, and lower image contrast. The 39-percent central obstruction introduced by the secondary mirror also decreases image contrast.

The VMC110L includes a built-in flip mirror, which eliminates the need for a separate star diagonal. Flip the integrated lever up, and the light pops straight out the back of the telescope (great for imaging). Flip the lever down, and it comes out a top-mounted eyepiece port, which works better for visual use. One image is flipped left-to-right compared to the other.

The VMC110L attaches to the Skypod's side-mounted cradle with a standard Vixen Optics dovetail plate. The entire setup weighs only 19 pounds (8.6 kg) — an easy one-hand carry. Because you don't need charts thanks to the Starbook S, this is truly grab-and-go astronomy.

VIXEN'S SKYPOD MOUNT with its Starbook controller provides full go-to capability in a lightweight package. There's nothing light about the Starbook's database, though — you'll find 22,000 celestial objects in it. ALL PHOTOS: *ASTRONOMY*: WILLIAM ZUBACK

THE SKYPOD'S Starbook controller detaches from the mount for "corded-remote" operation. Its 46"-long (1.17 meters) cable allows you to control the Skypod comfortably whether seated or standing.

STAR BOOK Type S
Vixen
SKYPOD
Vixen
ON
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DC12V

COUPLE VIXEN'S VMC110L telescope and aluminum tripod with the Skypod mount, and you'll have a system light enough for any observer to transport.

Driving with the Starbook

The Starbook initializes unlike any other go-to drive I've worked with, and, as such, it took a little getting used to. The instructions say to set up the telescope and tripod so the scope faces west and the mount's altitude axis aims north. An approximation is good enough, because you'll refine the telescope's aim during initialization.

When you first turn on the Starbook's power, it displays the company logo and then asks what language you prefer. Japanese (default), English, French, German, Italian, and Spanish all come factory-installed. Toggle between the choices and then press the SELECT button to confirm. The Starbook also asks for the local time, date, and location. Input these using the same menu buttons.

I had two problems using the buttons for these and other tasks. Although Vixen designed the buttons to be large enough to press while wearing gloves, they are not backlit. Instead, I had to use a flashlight to see which button I was pushing.

The second problem was more ergonomic. The 2" by 2" monochromatic-blue LCD screen displays the two sets of buttons with small prompts inside, each telling what that button is configured to do. But while the buttons are oriented vertically on the Starbook S panel, they are displayed side-by-side on the screen. The left set on the screen corresponds with the top set on the box, while the right set on the screen matches the bottom set on the box. It would have made operation more intuitive if the button placement matched the display, and vice versa.

I hope Vixen corrects this second issue with a future update to the Starbook S software. Upgrades give this mount a huge advantage over manual mounts or those with non-updatable software. Check Vixen's web site, www.vixenoptics.com, and click "Support" then "Downloads." Follow the instructions to get the latest version.

The Starbook runs in two different modes, Chart Mode and Scope Mode. Use Chart Mode when searching for objects on the LCD screen without moving the telescope, such as during the initial alignment process. Scope Mode moves the telescope in step with the displayed sky chart.

To align the Skypod, select two different reference objects either by centering an object in the crosshairs on the LCD screen in Chart Mode or from a menu that appears after pressing the "Object" button. Pressing "Goto" slews the telescope to the chosen object. Once there, use the up-down and left-right buttons to center the target, first in the red-dot finder, and then in the eyepiece. You can adjust the slewing rate by zooming the LCD chart in and out, which narrows or expands the sky coverage displayed. Although the initialization process was a little confusing the first time I tried it, it soon became almost second nature.

Phil Harrington *is a contributing editor of* Astronomy. *Check out the fourth edition of his book* Star Ware *(Wiley, 2007).*

/// SPECIFICATIONS

VIXEN SKYPOD + VMC100L

Type: Computerized, alt-azimuth mount
Aperture: 4.33 inches (110mm)
Focal ratio: f/9.4
Focal length: 1,035mm
Starbook controller: Attaches with 46" (1.17m) cable; detachable for use as pocket planetarium
Display: 2" by 2" (51mm by 51mm) monochromatic, backlit LCD
Database: 22,000 objects
Power: 12 volts DC (8 AA batteries or optional external power supply)
Price: $799 (Skypod only); $899 (Skypod with tripod); $999 (Skypod, tripod, and the VMC110L scope)

Targeting the sky

After I aligned the Skypod and Starbook with two known stars, it was time to put the telescope through its paces. Each time, pointing accuracy was good enough to get the target in or near the field of the 25mm eyepiece. After centering each subsequent object in the view, I found that pressing the "Align" button further improved the mount's pointing accuracy.

The Starbook's built-in library includes some 14,000 stars down to 7th magnitude, all of the Messier objects, nearly 5,000 NGC and IC objects down to 14th magnitude, as well as the Sun, Moon, and planets — all organized into several categories. The "Famous Object" list sorts deep-sky objects by their popular names, although it lists the Crab Nebula (M1) as the "Club Nebula." I expect Vixen's next update to correct this.

In actual use, the Starbook's LCD backlit display worked well until temperatures dropped below freezing. Strapping a hand-warmer to the back of the case with a rubber band, however, helped restore the image. The motors inside the Skypod also performed sluggishly at temperatures below about 20° F (–7° C).

Speaking of power, the mount cannot be used in manual mode. So it's best to bring along an extra set of batteries just in case. Better still, plug the Skypod into a 12-volt rechargeable car battery jump-starter.

With the Starbook and Skypod both operational, it was time to put the VMC110L through its paces. I began star testing the telescope at 205x using a 5mm eyepiece. In a perfect scope, out-of-focus should appear perfectly round and identical on both sides of focus. Defocusing star images through the scope revealed circular, but disparate, patterns indicative of spherical aberration. As magnification increased, the impact spherical aberration had on image quality became more apparent.

I was pleased with what I saw every time through the supplied 25mm Plössl eyepiece (which yielded 41x), whether it was the Orion Nebula, any of winter's bright open star clusters, or the Moon.

Focusing was smooth with little image shift, but images began to soften when I switched to a 10mm eyepiece (102x). Although I could see the Cassini Division in Saturn's rings, for instance, it was not as sharp as in my own 4-inch Vixen refractor with the same eyepiece.

The bottom line

Vixen's Skypod is an innovative design that takes grab-and-go astronomy to a new level, thanks to the Starbook. Although a couple of ergonomic issues exist, the Starbook includes more than enough target objects to entertain its owner for years. And the compact VMC110L catadioptric telescope performs fine as long as you don't push its magnification beyond about 100x. Together, they make a great travel team if you're jetting off to a dark location and want to keep everything together in a single, neat package.

CONTACT INFORMATION

Vixen Optics
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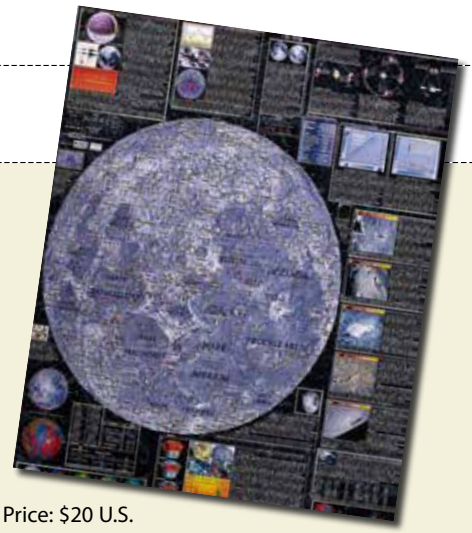

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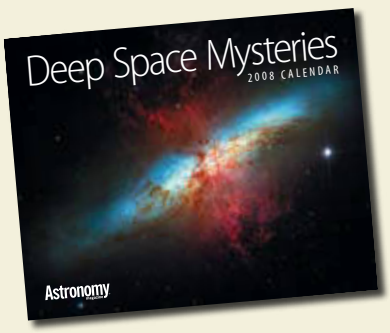

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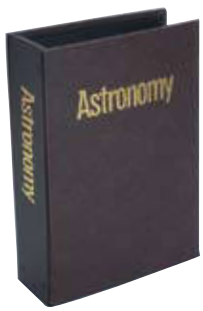

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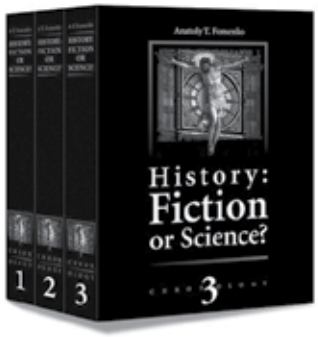

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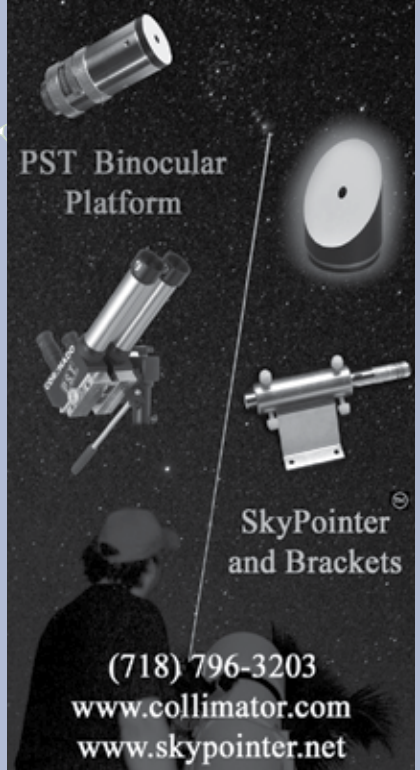

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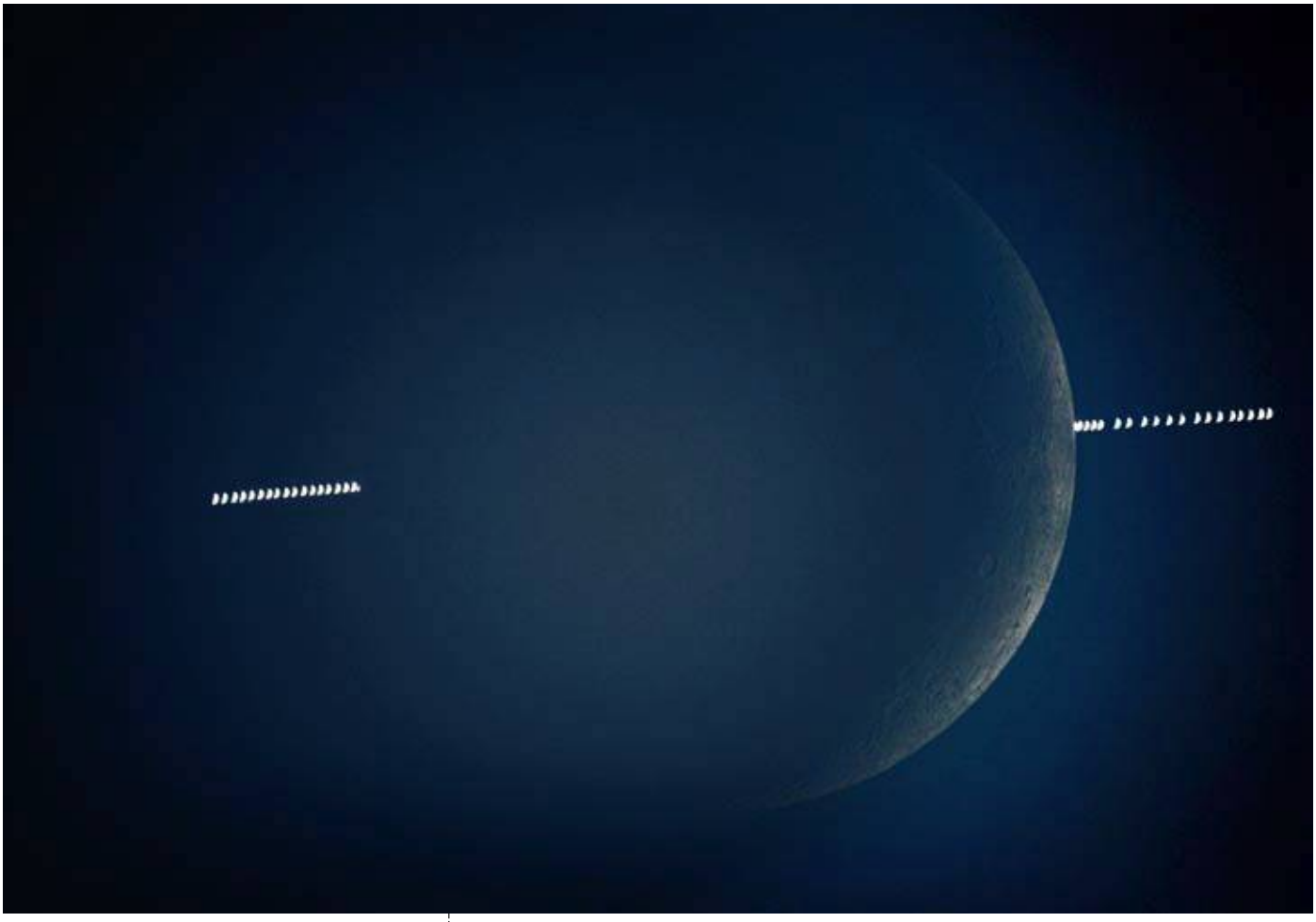


OCCULTATION OF VENUS (10-inch Meade Schmidt-Cassegrain telescope at f/6.3, Canon EOS 300D digital SLR, composite image with 1/800-second and 1/1,000-second exposures spaced from 1 to 3 minutes apart)
/// **TUNC TEZEL, BURSA, TURKEY**

PLANETARY OCCULTATION

The Moon hides Venus

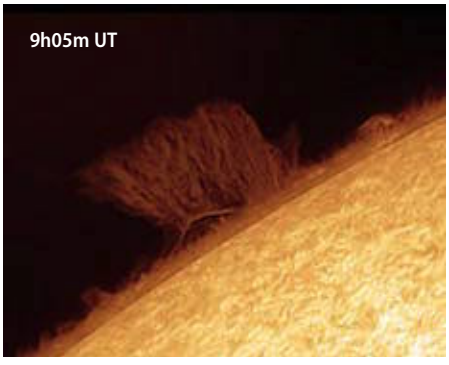
An occultation occurs when one celestial object passes in front of another. An eclipse is one type of occultation. This composite image shows the crescent Moon covering Venus between 20h47m UT and 22h41m UT June 18, 2007. Before Venus disappeared, the photographer spaced the images evenly, taking one every minute with a telescope and focal-reducer setup.

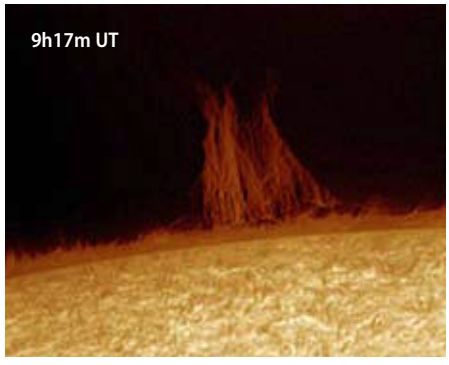
For the first five images of Venus, he used eyepiece-projection through a 17mm Plössl eyepiece attached to a 10-inch telescope. He took the last 14 images at intervals of 1.5 to 3 minutes. For these images, he used the telescope and camera only.

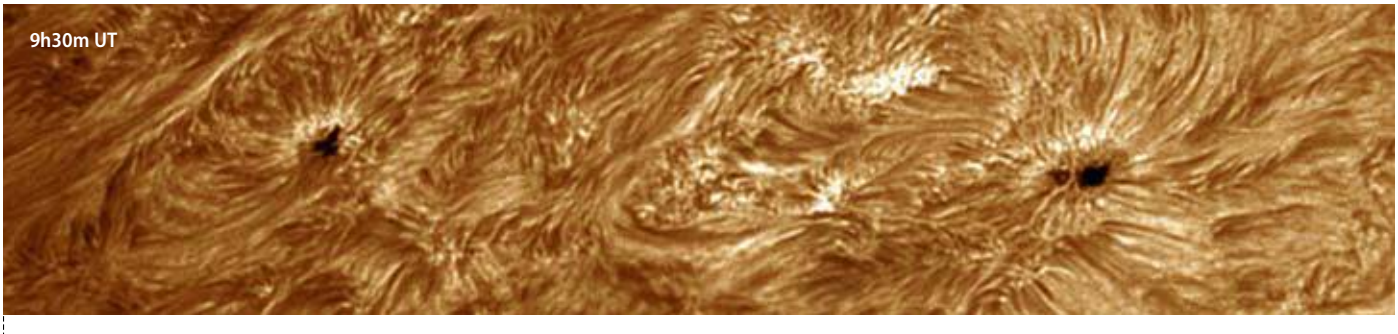
Send your images to: *ASTRONOMY* Reader gallery, P. O. Box 1612, Waukesha, WI 53187. Please include the date and location of image and complete photo data: telescope, camera, and exposure information. To submit images electronically, visit www.contribute.kalmbach.com.

GLOBULAR CLUSTER M9 in Ophiuchus measures 12' across and glows at magnitude 7.8. The dark nebula to M9's right is B64. (4-inch Tele Vue NP101 at f/5.4, SBIG ST-2000XM CCD camera, LRGB image with exposures of 120, 108, 54, and 54 minutes, respectively) /// **BERNHARD HUBL, SCHLIERBACH, AUSTRIA**

DOUBLE STAR M40 in Ursa Major, also known as Winnecke 4, is a unique entry in Messier's catalog. This image's brightest galaxy is NGC 4290. (6.4-inch Astro-Physics Starfire EDF at f/7.5, SBIG ST-2000XM CCD camera, LRGB image with 30-minute exposures in each channel) /// **ANTHONY AYIOMAMITIS, ATHENS, GREECE**

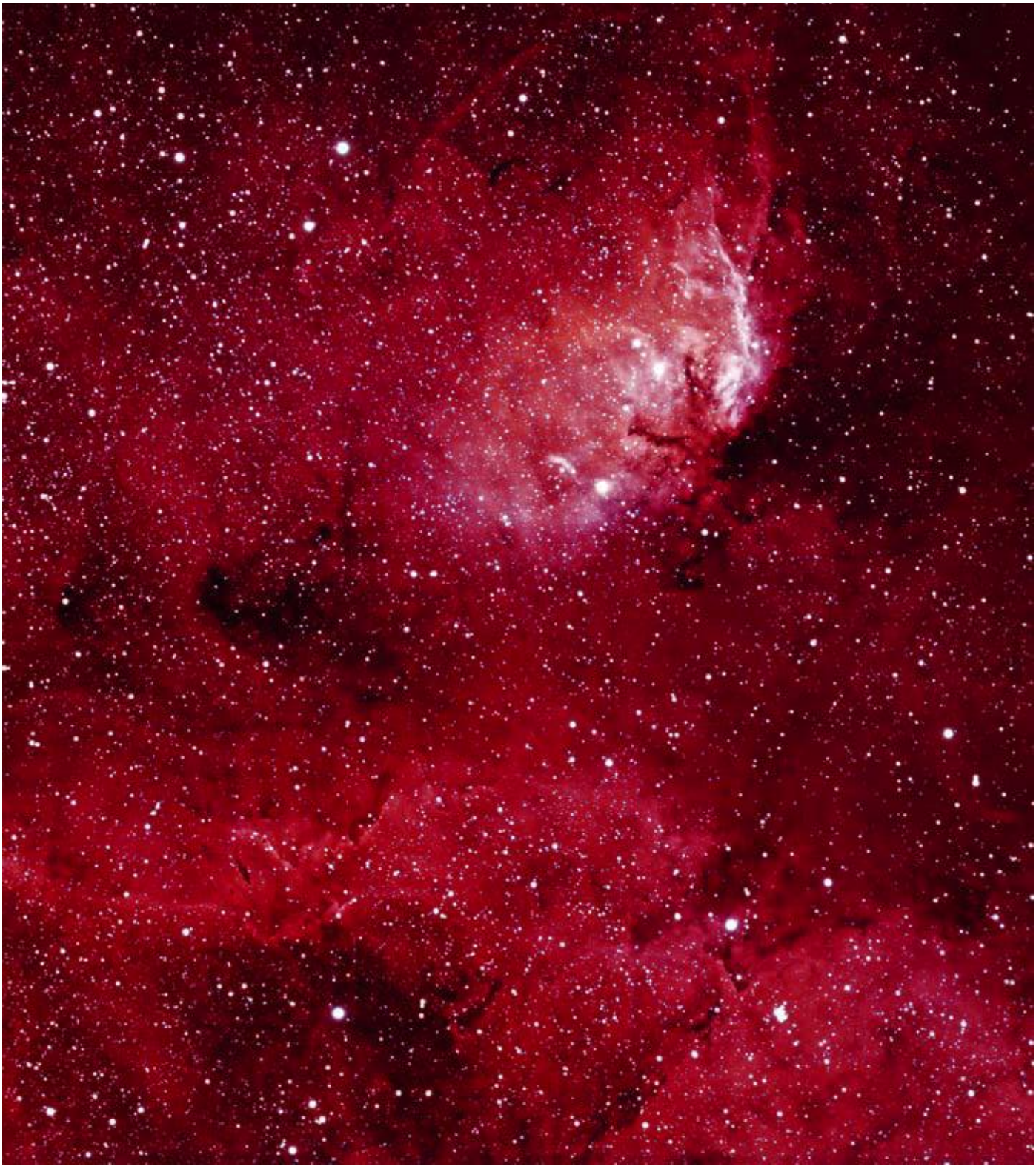






HYDROGEN-ALPHA (Hα) solar images show lots of detail. Flares, prominences, and the Sun's mottled surface become visible through Hα filters. (4-inch Takahashi FS102 at f/40, DayStar 0.6 Angstrom Hα filter, Lumenera LU075M CCD camera, 1/60-second exposures; approximately 200 frames combined per image, taken September 30, 2006) /// **DAMIAN PEACH, LOUDWATER, ENGLAND**

THE TULIP NEBULA (Sharpless 2–101) lies in Cygnus. This area is rich in Hydrogen-alpha (Hα) and ionized Sulfur (SII) emissions. Near the Tulip's center sits the star HDE 227018, which astronomers think is fueling the emissions. Nearby lies Cygnus X-1, the sky's brightest X-ray source. (8-inch TMB 203 apochromatic refractor at f/7, SBIG STL-6303 CCD camera, HαSIIRGB image with exposures of 300, 210, 48, 48, and 48 minutes, respectively) /// **NEIL FLEMING, WESTWOOD, MASSACHUSETTS**



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This incredible two frame mosaic of NGC 2170 was taken by Russ Croman with an SBIG STL-11000M camera through a 20" f/8 RC scope. The total exposure time was 16 hours per frame. Selected as NASA's Astrophoto of the Day, February 28, 2007.

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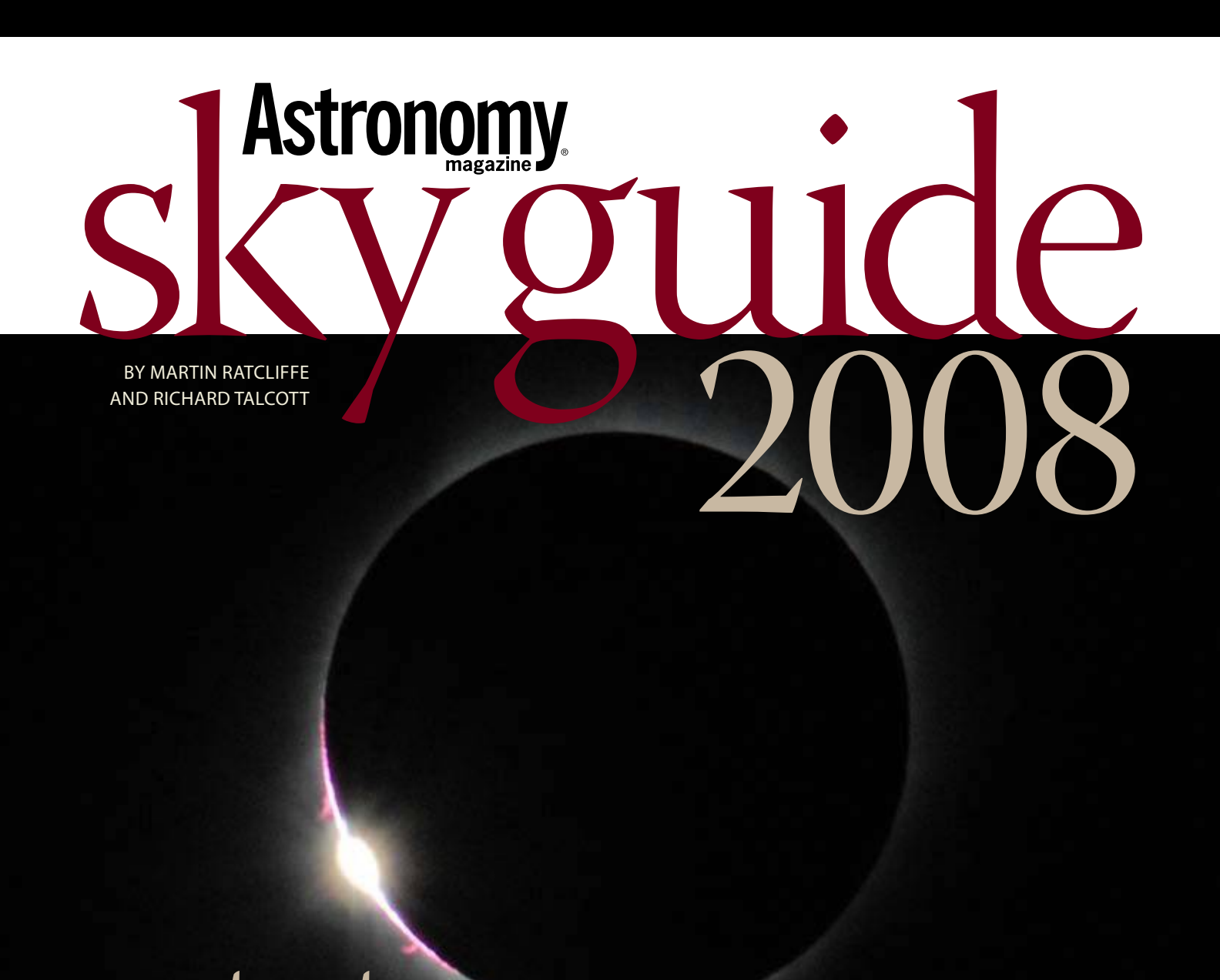
BY MARTIN RATCLIFFE
AND RICHARD TALCOTT



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XIV **DEC 2008** Dancing with the planets
XV **JAN 2009** A worthy comet returns to view

A DIAMOND RING of sunlight peeks through a deep lunar valley, signaling the start of totality. Observers in parts of Russia and China will witness a total solar eclipse August 1. JUDY BOWEN

Martin Ratcliffe *is the former president of the International Planetarium Society.* **Richard Talcott** *is a senior editor of* Astronomy *magazine.*

618189

A supplement to *Astronomy* magazine

2007 Dec

S	M	T	W	T	F	S
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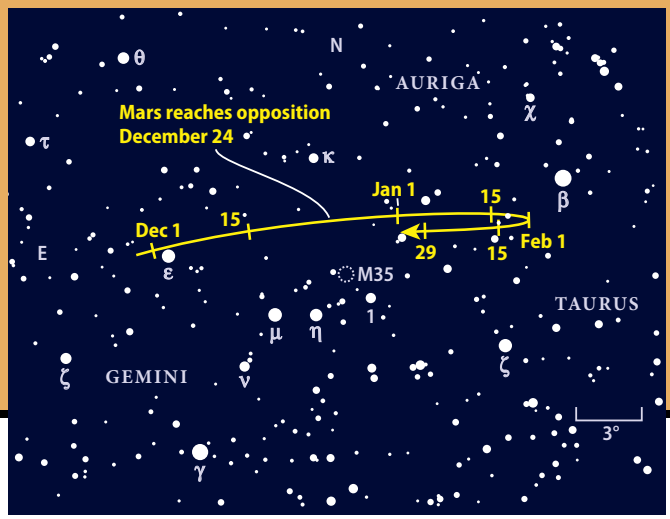
30	◐					

Mars rules the winter sky



MARS GLEAMS high in the evening sky in late 2007 and early 2008, as it treks through Gemini and Taurus. *ASTRONOMY:* ROEN KELLY

As 2007 winds down, the Red Planet ramps up to its best showing in more than 2 years. Mars reaches opposition and peak visibility December 24, when it shines brightest and remains visible all night. The planet then shines at magnitude –1.6, brighter than any star and dimmer only than Venus and the Full Moon in the night sky.

As a bonus, Mars passes nearly overhead around midnight for Northern Hemisphere observers. The planet lies in Gemini, the northernmost constellation along the ecliptic, and stands within 20° of the zenith for at least 2 hours each night. The high altitude helps those targeting Mars with a telescope, because the planet's light travels through less of Earth's turbulent atmosphere.

And telescopic observers may need the help. Mars won't be as close to Earth at this opposition as it has been recently. At closest approach, the planet lies 55 million miles away. This means Mars' 4,220-mile diameter subtends an angle of 16", noticeably smaller than at the previous three oppositions, when its disk appeared larger than 20".

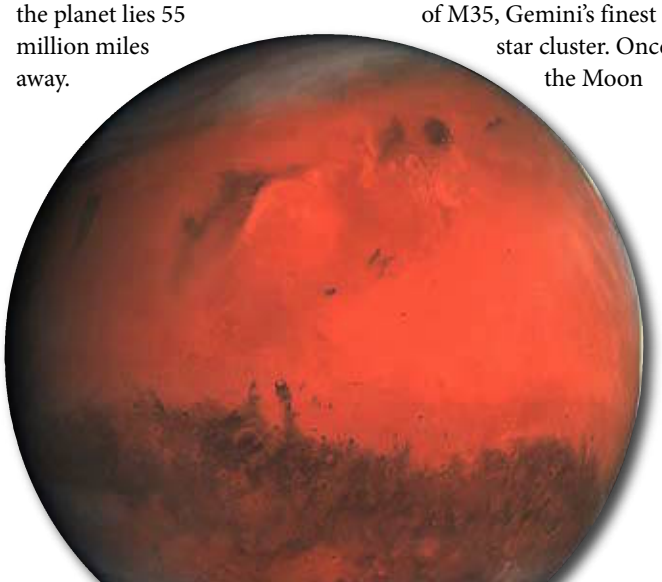
Still, Mars will show lots of detail through small- and medium-sized telescopes, and will appear stunning through large scopes. The disk's most obvious feature will be the white north polar cap, now near its maximum extent as the northern hemisphere's long winter concludes. Also look for Syrtis Major, the planet's darkest region, and the bright Hellas basin.

One night before opposition, on December 23, a Full Moon sits just 1° (2 Moon diameters) from Mars. At the same time, Mars lies 2.5° north of M35, Gemini's finest star cluster. Once the Moon departs a few nights later, binoculars will deliver a nice view of Mars and M35 together.

Although Mars' apparition peaks in December, the planet is a fine sight through early 2008. Its disk exceeds 10" in diameter — big enough to show fine detail — until the latter half of February. It remains a conspicuous naked-eye object even longer. It shines at 1st magnitude or brighter as it plies the evening sky through the end of May.

The Red Planet concludes its westward march against the background stars in late January, then resumes its typical eastward motion. It returns to M35's vicinity in early March, this time passing less than 2° north of the cluster. And it pierces the heart of the large Beehive star cluster (M44) in Cancer from May 21 to 23.

On July 10/11, Mars passes less than 1° from Saturn in the western sky after sunset. The Red Planet comes even closer to Venus September 11, although bright twilight will lessen the impact of this conjunction.



THE RED PLANET peaks in late December 2007, and will remain a fine telescopic sight through February. ESA/MPS

- **01** The Moon passes 2° south of Saturn, 8 A.M. EST
- **05** The Moon passes 7° south of Venus, 8 P.M. EST
- **14** Geminid meteor shower peaks
- The Moon passes 0.7° south of Neptune, 1 P.M. EST
- **16** The Moon passes 2° north of Uranus, 1 P.M. EST
- **17** Mercury is in superior conjunction, 10 A.M. EST
- **20** Pluto is in conjunction with the Sun, 7 P.M. EST
- **22** Solstice (northern winter/southern summer begins), 1 A.M. EST
- **23** Jupiter is in conjunction with the Sun, 1 A.M. EST
- The Moon passes 0.9° north of Mars, 10 P.M. EST
- **24** Mars is at opposition, 3 P.M. EST
- **27** The Moon passes 0.6° south of Regulus, midnight EST
- **28** The Moon passes 3° south of Saturn, 5 P.M. EST
- **30** Comet 8P/Tuttle passes M33

FOR MORE on these and other sky events and news throughout the year, go to Astronomy.com.

A comet's impressive return

COMET C/2001 Q4 (NEAT) passed the Beehive star cluster (M44) in 2004. Comet 8P/Tuttle skirts the spiral galaxy M33 in late December 2007. MICHAEL JÄGER AND GERALD RHEMANN

Get set for the best view of Comet 8P/Tuttle since 1980. The comet reaches its closest point to Earth January 1, when it lies 23.5 million miles away and should glow at 6th magnitude. At this brightness, it will be an easy binocular object. During the previous week, Tuttle lies overhead in the early evening for observers at mid-northern latitudes. It remains well placed in the south throughout the first half of January.

The comet crosses the constellation Andromeda during December's final week. It passes between Beta (β) and Gamma (γ) Andromedae December 28 as its path carries it south about 4° per day. On the 30th, Tuttle lies in front of the Pinwheel Galaxy (M33) in Triangulum. As January opens, the comet lies 6° west of Alpha (α) Arietis.

During the second week of the new year, Tuttle heads south through Cetus, fading slowly as it recedes from Earth. By the 14th, a waxing Moon hurts the comet's visibility, ending the period of favorable viewing. The comet won't reappear until 2021.

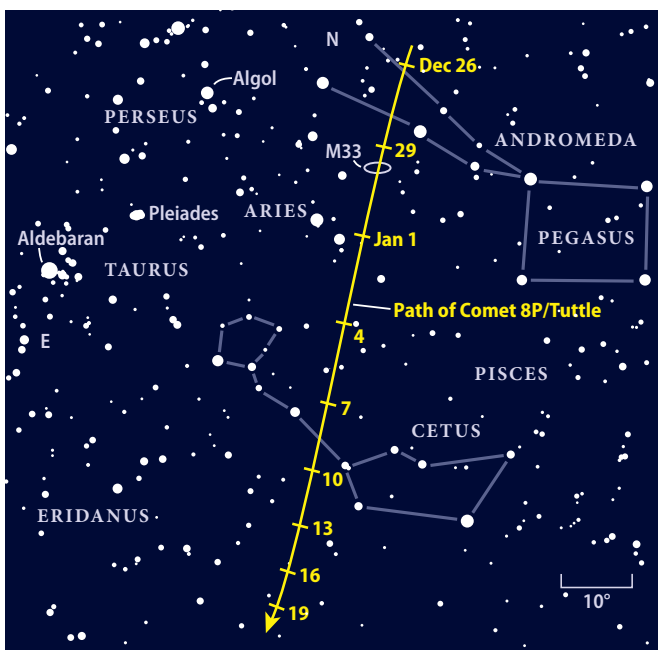
American astronomer Horace Tuttle discovered this comet 150 years ago, on the night of January 4/5, 1858. Once scientists calculated its 13.6-year orbit, they realized French observer Pierre Méchain had previously spotted it in 1790.

Comets are dusty iceballs that orbit the Sun on elongated paths. When one passes through the inner solar system, the Sun heats its surface enough that the ices sublimate, or turn directly to gas.

The gas and dust liberated from the nucleus give the comet a tenuous and temporary atmosphere, which astronomers call a "coma." Most comets retain this roughly spherical cloud throughout their stay in the inner solar system.

The prettiest comets visually also possess one or two tails. Solar radiation pressure nudges the coma's dust particles away from the Sun, while the solar wind performs a similar trick with the coma's ionized gas. To best see Tuttle's dust and gas tails, view the comet with both binoculars and a telescope.

After innumerable trips through the inner solar system, Comet Tuttle has now deposited dusty debris along its entire track. Each year around December 22, Earth runs into this debris stream, creating the Ursid meteor shower. Unfortunately, a Full Moon will wash out most of the 2007 shower.



2008 Jan

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13	14	◑	16	17	18	19
20	21	●	23	24	25	26
27	28	29	◐	31		

04 Quadrantid meteor shower peaks

05 The Moon passes 7° south of Venus, 1 A.M. EST

The Moon passes 0.5° south of Antares, 5 A.M. EST

06 Venus passes 6° north of Antares, 9 P.M. EST

10 The Moon passes 0.4° south of Neptune, 8 P.M. EST

12 The Moon passes 3° north of Uranus, 8 P.M. EST

19 The Moon passes 1.1° north of Mars, 7 P.M. EST

21 Mercury is at greatest eastern elongation (19°), midnight EST

24 The Moon passes 0.7° south of Regulus, 10 A.M. EST

25 The Moon passes 3° south of Saturn, 1 A.M. EST

Events that can be viewed with **the naked eye**

Events that can be viewed with **binoculars**

Events that can be viewed with a **telescope**

◀ **COMET 8P/TUTTLE should peak near 6th magnitude as 2007 turns to 2008. Try to spy it before it dips too far south in late January.** *ASTRONOMY:* ROEN KELLY

Feb 2008

S	M	T	W	T	F	S
					1	2
3	4	5	○	7	8	9
10	11	12	◑	14	15	16
17	18	19	●	21	22	23
24	25	26	27	◐	29	

Totality's last stand

AN ECLIPSED MOON typically appears orange or red because Earth's atmosphere filters out blue light and bends red light into our planet's shadow. BRUCE BAKINGSLEY

The third total lunar eclipse to grace North America's sky in the past year occurs the evening of February 20. Europeans will see the same event in the early morning hours of February 21. The eclipsed Moon lies in Leo, with Saturn just 4° away.

Lunar eclipses always occur at Full Moon, when the Sun, Earth, and Moon line up precisely and Earth casts its shadow on the Moon. Because the Moon's orbit tilts 5° to Earth's orbit around the Sun (the ecliptic), eclipses don't occur at every Full Moon. Only when the Full Moon lies on the ecliptic does Earth's shadow block sunlight from reaching the Moon's surface.

But the Moon doesn't disappear during totality. Earth's light-bending atmosphere, which causes the Sun to turn orange or red at sunset, redirects this colored light into the shadow. As a result, the Full Moon's color changes from brilliant white to somewhere between bright orange and dull red. The color's intensity depends on the state of Earth's atmosphere. For example, if lots of dust from recent volcanic eruptions permeates the atmosphere, the eclipse will be dark.

The February 20/21 eclipse begins when the Moon's western limb (the left-hand edge) touches Earth's outer penumbral shadow. Because plenty of sunlight still penetrates the penumbra, the Moon doesn't darken much. The first obvious sign of the eclipse comes when the Moon enters the dark umbral shadow at 8:43 P.M. EST (5:43 P.M. PST). This signifies the start of the partial eclipse, which will be visible throughout North America except along the Pacific Coast.

During the next 78 minutes, the shadow's dark edge will creep across the lunar surface. As an experiment, time the moment the shadow reaches each major crater. (You'll need to observe with binoculars or a telescope to get accurate timings.) As totality approaches, the dark shadow shows more color as the harsh contrast between it and the rest of the Moon lessens.

Totality begins at 10:01 P.M. EST (7:01 P.M. PST) and lasts 50 minutes. During the total phase, try to estimate how dark the shadow appears. Is it a brilliant orange or a dull red? Look for subtle color variations across the shadow. The Moon's southern edge will appear brighter because the Moon crosses the southern part of Earth's shadow and doesn't reach the deeper, darker, central region. The Moon's more-reflective southern highlands will accentuate this brightness.

Don't miss this opportunity to witness totality — you'll have to wait until December 20/21, 2010, for the next total lunar eclipse.

SATURN AND REGULUS nicely frame February 20's totally eclipsed Moon, which will be visible throughout North America. *ASTRONOMY*: ROEN KELLY

- 01 Venus passes 0.6° north of Jupiter, 8 A.M. EST
- The Moon passes 0.6° south of Antares, 1 P.M. EST
- 04 The Moon passes 4° south of Jupiter, 1 A.M. EST
- The Moon passes 4° south of Venus, 7 A.M. EST
- 06 Mercury is in inferior conjunction, 1 P.M. EST
- Annular solar eclipse, 11 P.M. EST
- 09 The Moon passes 3° north of Uranus, 5 A.M. EST
- 10 Neptune is in conjunction with the Sun, 9 P.M. EST
- 16 The Moon passes 1.6° north of Mars, 3 A.M. EST
- 20 Asteroid Vesta is in conjunction with the Sun, 10 A.M. EST
- The Moon passes 0.7° south of Regulus, 7 P.M. EST
- Total lunar eclipse, 11 P.M. EST
- 21 The Moon passes 3° south of Saturn, 7 A.M. EST
- 24 Saturn is at opposition, 5 A.M. EST
- 25 Mercury passes 1.3° north of Venus, 10 P.M. EST
- 28 The Moon passes 0.6° south of Antares, 10 P.M. EST

See Saturn's rings while you can

SATURN'S RINGS appear as a thin streak this year in anticipation of turning edge-on in 2009. NASA/ESA/THE HUBBLE HERITAGE TEAM (STScI/AURA)

As darkness falls these March evenings, Saturn dominates the eastern sky. The ringed planet climbs higher each passing night and looks spectacular through a telescope.

Saturn normally lays claim to the title of "most beautiful planet." But even a quick glance at low power shows a planet markedly different from the past several years: The rings no longer open wide to our view. Saturn's 2008 appearance serves as prelude to 2009, when the rings turn edge-on to Earth and will disappear.

Saturn reaches opposition and peak visibility this year February 24. It then lies 771 million miles from Earth, and the 74,900-mile-wide planet appears 20" in diameter. The rings' long axis spans 45", but their small axis stretches a mere 7". On nights with steady seeing, a 3-inch or larger telescope should reveal the Cassini Division, a dark gap that separates the outer A ring from the brighter B ring.

As the rings have narrowed during the past few years, the planet's disk has come into better view. The dark southern equatorial belt is fairly obvious in most scopes. Larger scopes reveal more belts, although they appear markedly more subtle than those on Jupiter.

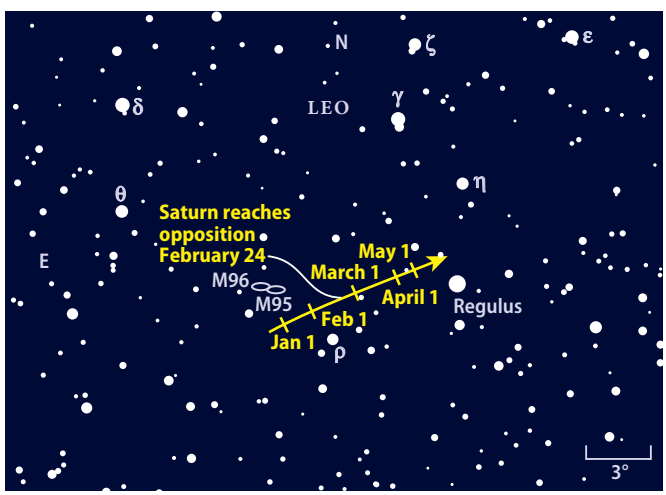
A 3-inch scope also reveals Saturn's largest moon, 8th-magnitude Titan. It's usually the brightest point of light near the planet, although background stars occasionally confuse the issue. Watch for a few nights, and you should detect the moon's orbital motion.

Large scopes show several fainter moons. Easiest to see are 10th-magnitude Tethys, Dione, and Rhea. To see the inner moons Enceladus (12th magnitude) and Mimas (13th magnitude), observe when they lie farthest from Saturn's glare.

The planet's most unusual moon is outer Iapetus. It glows more than 5 times brighter when it lies farthest west of the planet (magnitude 10.1) than when it is farthest east (magnitude 11.9).

Saturn spends 2008 among the background stars of Leo the Lion. It starts the year near the bright spiral galaxies M95 and M96. By April, Saturn's westward motion brings it within 2° of 1st-magnitude Regulus, Leo's brightest star. The planet shines a full magnitude brighter than Regulus.

Saturn remains visible throughout spring and early summer. From July 9 to 11, it appears within 1° of Mars, forming a pretty pair in the twilight. Saturn passes on the far side of the Sun at conjunction September 3, then returns to the morning sky for the rest of the year.



SATURN SLIDES through southern Leo this winter and spring, not far east of the 1st-magnitude star Regulus.

ASTRONOMY: ROEN KELLY

2008 March

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9	10	11	12	13	◑	15
16	17	18	19	20	●	22
23	24	25	26	27	28	◐
30	31					

- 02 The Moon passes 4° south of Jupiter, 8 P.M. EST
- 03 Mercury is at greatest western elongation (27°), 6 A.M. EST
- 05 The Moon passes 0.2° south of Mercury, 9 A.M. EST
- The Moon passes 0.2° north of Venus, 2 P.M. EST
- The Moon passes 0.2° south of Neptune, 5 P.M. EST
- 06 Venus passes 0.6° south of Neptune, 3 P.M. EST
- 08 Uranus is in conjunction with the Sun, 3 P.M. EST
- Mercury passes 0.9° south of Neptune, 10 P.M. EST
- 14 The Moon passes 1.7° north of Mars, 11 P.M. EDT
- 19 The Moon passes 0.8° south of Regulus, 4 A.M. EDT
- The Moon passes 3° south of Saturn, 11 A.M. EDT
- 20 Equinox (northern spring/southern autumn begins), 2 A.M. EDT
- 23 Mercury passes 1.0° south of Venus, 6 A.M. EDT
- 27 The Moon passes 0.5° south of Antares, 6 A.M. EDT
- 30 The Moon passes 3° south of Jupiter, 1 P.M. EDT

2008
April

S	M	T	W	T	F	S
		1	2	3	4	○
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13	14	15	16	17	18	19
●	21	22	23	24	25	26
27	◐	29	30			

02 The Moon passes 0.002° north of Neptune, 5 A.M. EDT

04 The Moon passes 3° north of Uranus, 6 A.M. EDT

The Moon passes 5° north of Venus, 9 P.M. EDT

12 The Moon passes 1.2° north of Mars, 2 A.M. EDT

15 The Moon passes 0.9° south of Regulus, 10 A.M. EDT

The Moon passes 3° south of Saturn, 2 P.M. EDT

16 Mercury is in superior conjunction, 3 A.M. EDT

22 Lyrid meteor shower peaks

23 The Moon passes 0.3° south of Antares, 1 P.M. EDT

27 The Moon passes 3° south of Jupiter, 1 A.M. EDT

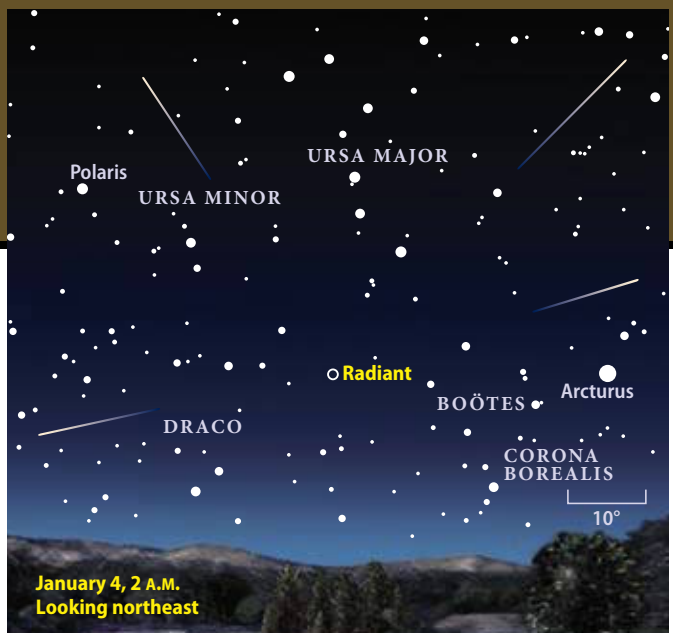
28 Mars passes 5° south of Pollux, 4 P.M. EDT

29 The Moon passes 0.3° north of Neptune, 3 P.M. EDT

Meteor thrills for 2008

THE BEST METEORS of 2008 likely will come from January's prolific Quadrantid shower.

ASTRONOMY: ROEN KELLY



The fleeting glimpse of a shooting star evokes a sense of awe in the young and old alike. Yet understanding where these flashes of light come from can inspire a deeper appreciation. Shooting stars begin life as comet dust, samples of material little changed since the solar system's birth.

A comet ejects dust particles whenever its orbit brings it near the Sun. Frequent solar passages eventually litter the comet's orbit with tiny dust particles. If the comet's orbit intersects Earth's, some of those dust bits collide with our planet. The sand-grain-sized particles strike the atmosphere at tremendous speeds, and the impact energy fries them within a second. Their last exhalation is a fiery glow — a streak of light observers on the ground see as a meteor.

Fewer than a dozen major meteor showers hit us each year. Most give similar performances from one year to the next, although astronomers can't predict the exact number of meteors a person will see from a given spot. The Moon's presence brightens the background sky and reduces the number of meteors visible. Light pollution has the same effect, so try to observe far from the city.

This month's lone shower, the Lyrids, peaks April 22. Unfortunately, these meteors must contend with a 2-days-past-full Moon. By late April, however, the Eta Aquarid shower ramps up. Its May 4 peak comes 1 day before New Moon. Nice spring weather and a moonless night should make this one of 2008's best showers, producing perhaps 20 to 30 meteors per hour.

The three strongest annual meteor showers are January's Quadrantids, August's Perseids, and December's Geminids, which regularly produce at least one meteor per minute under ideal conditions. Of these three, only the Quadrantids escapes major interference from the Moon this year. Its short period of activity runs from January 1 to 5, with the peak coming the 4th. With New Moon January 8, viewing conditions should be great, if a bit cold.

A GEMINID METEOR streaks through the treetops. A Full Moon will hinder views of this year's shower. PIERRE MARTIN

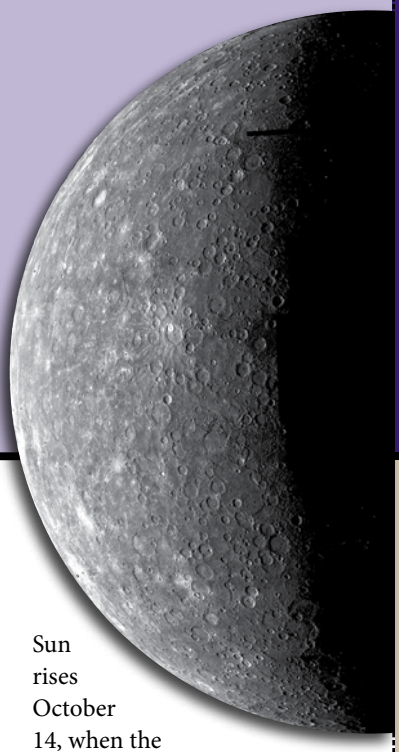
The Perseids don't fare so well. A Full Moon occurs 4 nights after the shower's August 12 maximum. This means a bright gibbous Moon will share the sky on peak night.

The Geminids, which climax December 13, have to contend with a Moon just 1 day past full. Fortunately, both of these showers produce many bright meteors, so they are worth viewing.

/// METEOR SHOWERS IN 2008

Name	Peak date	Moon's phase	Prospects
Quadrantids	Jan. 4	Waning crescent	Good
Lyrids	April 22	Waning gibbous	Poor
Eta Aquarids	May 4	New Moon	Excellent
Perseids	Aug. 12	Waning gibbous	Poor
Orionids	Oct. 21	Last quarter	Fair
Leonids	Nov. 17	Waning gibbous	Poor
Geminids	Dec. 13	Full Moon	Poor

Mercury's fleet-footed wanderings



CRATERED MERCURY is too small and too near the Sun to show more than a featureless disk through earthbound telescopes. NASA/JPL

The solar system's apparently shy and elusive innermost planet makes two good appearances this year for Northern Hemisphere observers. The best times to view Mercury come May evenings and October mornings. On both occasions, Mercury lies relatively far from the Sun, and the ecliptic — the apparent path of the Sun across our sky, which the planets follow closely — inclines steeply to the horizon. The combination raises the planet into a relatively dark sky.

Mercury springs out from behind the Sun during the last week of April and climbs into the evening sky. Observers might spot the planet in bright twilight April 25, when it shines at magnitude –1.3.

By April 28, now at magnitude –1.1, Mercury lies directly below the Pleiades star cluster (M45). Over the next 4 nights, the planet passes south of the cluster, creating a wonderful photographic opportunity.

On May 2, Mercury lies 2° from M45 and glows at magnitude –0.8. A telescope reveals the planet's 69-percent-lit disk, which measures just 6" across.

Mercury's apparent size grows during May's first week as the planet speeds around its orbit and the distance between it and Earth tightens. A slender crescent Moon stands 3° to Mercury's upper right May 6, when the planet lies 7° high an hour after sunset. Two nights later, the disk appears half-lit, although it has faded to magnitude –0.2.

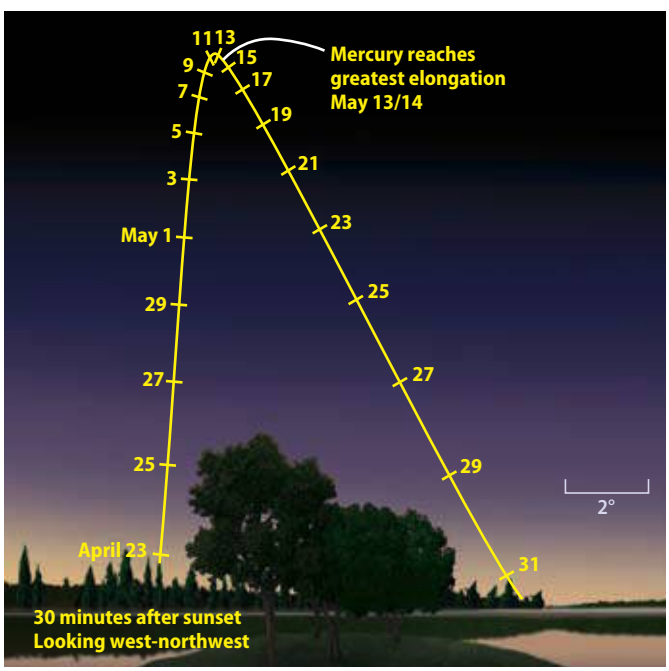
Mercury reaches greatest elongation May 13/14, when it lies 22° east of the Sun. It then shines at magnitude 0.3.

The telescopic view continues to impress for several more days. On the 18th, Mercury appears 9" across and shows a crescent just 25-percent lit. The planet's altitude falls rapidly after that, and it fades from view by month's end.

Mercury's best morning apparition of 2008 occurs in October. The view through a telescope repeats the planet's evening appearance, only in reverse. It will begin as a large, thin crescent, then fatten into a smaller, fully illuminated disk.

Your first easy view will come 30 minutes before the Sun rises October 14, when the 1.2-magnitude planet rises with the stars of Virgo. Saturn lies well above, in Leo. Within 3 days, Mercury has brightened by a magnitude and is unmistakable 4° above the eastern horizon an hour before sunrise.

At greatest elongation October 22, Mercury shines at magnitude –0.6 and rises 90 minutes before the Sun. Through a telescope, it displays a 7"-diameter disk that's 56-percent lit. By November's second week, the predawn twilight will swallow Mercury.



2008 May

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◑	12	13	14	15	16	17
18	●	20	21	22	23	24
25	26	◐	28	29	30	31

01	The Moon passes 3° north of Uranus, 7 P.M. EDT	🔭
04	Eta Aquarid meteor shower peaks	👁
06	The Moon passes 3° north of Mercury, 6 P.M. EDT	👁 🔭
10	Mercury passes 8° north of Aldebaran, 2 A.M. EDT	👁 🔭
	The Moon passes 0.2° north of Mars, 10 A.M. EDT	👁 🔭
12	The Moon passes 1.2° south of Regulus, 3 P.M. EDT	👁 🔭
	The Moon passes 3° south of Saturn, 8 P.M. EDT	👁 🔭
13	Mercury is at greatest eastern elongation (22°), midnight EDT	👁 🔭
20	The Moon passes 0.2° south of Antares, 7 P.M. EDT	👁 🔭
24	The Moon passes 2° south of Jupiter, 7 A.M. EDT	👁 🔭
26	The Moon passes 0.6° north of Neptune, 11 P.M. EDT	🔭
29	The Moon passes 4° north of Uranus, 5 A.M. EDT	🔭

◀ **MERCURY'S BEST SHOW** of 2008 comes in late April and early May, when the inner planet climbs high in evening twilight. *ASTRONOMY*: ROEN KELLY

2008
June

S	M	T	W	T	F	S
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8	9	◑	11	12	13	14
15	16	17	●	19	20	21
22	23	24	25	◐	27	28
29	30					

07 Mercury is in inferior conjunction, 11 A.M. EDT

The Moon passes 1.1° south of Mars, 10 P.M. EDT

08 Venus is in superior conjunction, midnight EDT

09 The Moon passes 3° south of Saturn, 5 A.M. EDT

12 Asteroid Juno is at opposition, noon EDT

17 The Moon passes 0.2° south of Antares, 1 A.M. EDT

20 The Moon passes 2° south of Jupiter, 9 A.M. EDT

Pluto is at opposition, 4 P.M. EDT

Solstice (northern summer/southern winter begins), 8 P.M. EDT

23 The Moon passes 0.8° north of Neptune, 5 A.M. EDT

25 The Moon passes 4° north of Uranus, noon EDT

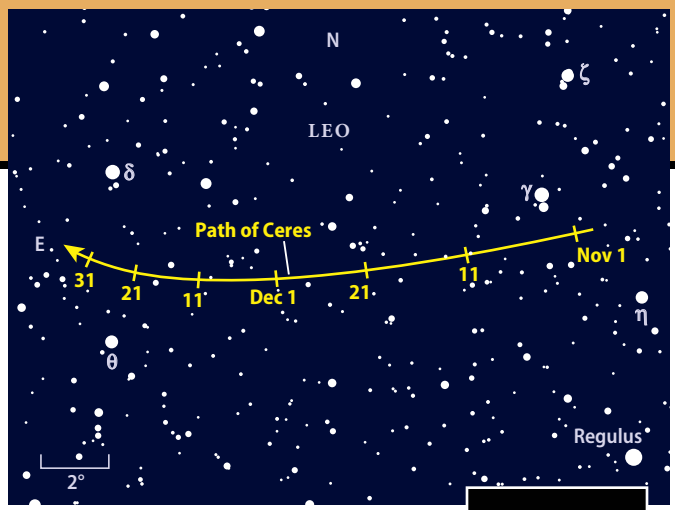
28 Asteroid Ceres is in conjunction with the Sun, 1 P.M. EDT

30 Mars passes 0.7° north of Regulus, midnight EDT

A dwarf-planet bonanza

▶ ASTEROID CERES TREKS through Cancer and Leo in late 2008, the best time this year to spy the brightest dwarf planet.

ASTRONOMY: ROEN KELLY



▶ DWARF-PLANET CERES appears as a dot from Earth, but the Hubble Space Telescope managed to image subtle color differences on its surface. NASA/ESA/STScI

By 2007, astronomers had pegged the number of dwarf planets in our solar system at three, although many more surely await discovery. The largest, Eris, is toughest to see because it lies far away and appears faint.

Second-in-size Pluto requires a good-sized telescope and a detailed finder chart. It reaches its peak this month. The smallest and closest, Ceres, shows up in binoculars in late 2008.

Spacecraft missions are targeting two of these dwarfs. Coincidentally, both will arrive in the same year: New Horizons will fly past Pluto in July 2015, while the Dawn mission will rendezvous with Ceres in February 2015. Here's a brief guide on how to track down the three dwarf planets.

Easiest to find is Ceres, the largest asteroid. After Giuseppe Piazzi discovered Ceres January 1, 1801, it was hailed as a new planet — just as Pluto would later be, until a family of other bodies in similar orbits changed its designation.

Ceres passes behind the Sun June 28, then climbs high into the morning sky late in the year as it brightens toward opposition. (This favorable apparition will peak in February 2009.) Your first view might come in early September, when Ceres passes 3° north of the Beehive star cluster (M44) in Cancer.

Glowing at 9th magnitude, Ceres will be easy to track with a small scope or a good pair of tripod-mounted 7x50 binoculars. In late October, it passes 2° north of Eta (η) Leonis, the bright star above Regulus, in Leo's Sickle asterism. By year-end, Ceres has brightened to 8th magnitude and will be an easy binocular object in eastern Leo.

You'll need a dark sky and an 8-inch or larger telescope to spot Pluto. Alternatively, you can image this dwarf planet with a CCD camera on a telescope that can capture 14th-magnitude objects.

Pluto reaches opposition June 20, when it lies 2.83 billion miles from Earth. At this staggering distance, Pluto brightens only to magnitude 13.9. To detect the faint object, you first need to pinpoint the correct field of view. This year, Pluto lies in the northwestern corner of Sagittarius, in a star field 6° north of the Trifid Nebula (M20) and 2° north of the open cluster M23.

Once you have the right field, observe it for a few nights, plotting each object you see. Pluto will reveal its identity by moving over time.

Eris proves to be the hardest dwarf planet to find. In fact, locating Pluto seems easy in comparison. You'll need to image Eris with a CCD setup that can record 19th-magnitude stars. The dwarf planet reaches opposition October 14, when it glows at magnitude 18.7 among the background stars of Cetus the Whale.

Some backyard observers have achieved 19th magnitude with an 8-inch scope by stacking multiple CCD exposures. If you're successful, send your images to *Astronomy*.

Jupiter's summer reign

JUPITER'S CLOUD TOPS burst with activity in 2007, with a disturbance in the South Tropical Zone and rapid changes in the South Equatorial Belt. CHRISTOPHER GO

The king of planets has no real competition this summer — the other planets appear inconspicuous at best. Fortunately, Jupiter presents lots of atmospheric structure to those with small telescopes, and astounding detail through 6-inch and larger scopes. It reaches the peak of its 2008 appearance at opposition July 9. Then it shines at magnitude –2.7 and reveals a striking disk 47" across to telescope owners.

The giant planet remains visible all year. It begins 2008 low in the morning sky, soars to all-night visibility at opposition, then wraps up the year in evening twilight.

Jupiter treks slowly among the background stars of Sagittarius this year. That's not great news for Northern Hemisphere observers, because the planet never climbs high in the sky.

A low altitude means light from Jupiter has to plow through thick layers of Earth's atmosphere to reach our telescopes, and the air's turbulence degrades planetary detail. The best views come in July, when the planet lies due south at local midnight (approximately 1 A.M. daylight time).

Jupiter underwent dramatic atmospheric changes in 2007, unlike any seen in recent years. Huge disturbances in the South Tropical Zone and a quiescent, then revived, South Equatorial Belt forged the planet's changing appearance.

You can expect at least some increased activity to continue into 2008. Meanwhile, the Great Red Spot has grown more prominent in the past couple of years.

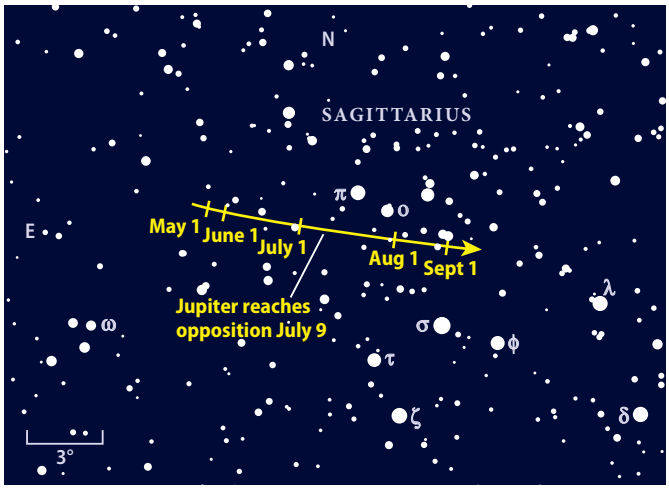
As fascinating as Jupiter's atmosphere will be, don't forget to view the planet's four major moons. Io, Europa, Ganymede, and Callisto circle Jupiter with periods ranging from less than 2 days (for inner Io) to more than 2 weeks (for outer Callisto).

Galileo discovered these four moons in 1610. They have historical significance because they proved our planet is not the center of all motion in the universe. It was a critical insight that helped lead to an understanding of Earth's place in the cosmos.

Once every orbit of Jupiter, each moon crosses the planet's disk. Although the moons can be hard to spot, they cast small but conspicuous black shadows on the planet's cloud tops. Io's fast-moving shadow changes position noticeably in just a few minutes. As each moon passes on the far side of Jupiter, the planet's shadow eclipses it. These eclipses show up best a month or more away from opposition, when the shadow lies well east or west of the planet's disk.

Jupiter and Venus meet twice this year. The two brightest planets have a spectacular conjunction February 1, when they lie a Moon-width apart. They rise in the southeast nearly 2 hours before the Sun.

The two meet again in the evening sky November 30, when they appear slightly farther apart but higher in the sky. The next evening, a slender crescent Moon joins them. The trio creates a stunning opener for December.



July 2008

S	M	T	W	T	F	S
		1	○	3	4	5
6	7	8	9	◑	11	12
13	14	15	16	17	●	19
20	21	22	23	24	◐	26
27	28	29	30	31		

01 The Moon passes 8° north of Mercury, 11 A.M. EDT

Mercury is at greatest western elongation (22°), 2 P.M. EDT

06 The Moon passes 3° south of Mars, 2 P.M. EDT

The Moon passes 3° south of Saturn, 6 P.M. EDT

09 Jupiter is at opposition, 4 A.M. EDT

11 Mars passes 0.7° south of Saturn, 2 A.M. EDT

14 The Moon passes 0.3° south of Antares, 8 A.M. EDT

17 The Moon passes 3° south of Jupiter, 8 A.M. EDT

20 The Moon passes 0.9° north of Neptune, 9 A.M. EDT

22 The Moon passes 4° north of Uranus, 6 P.M. EDT

29 Mercury is in superior conjunction, 4 P.M. EDT

◀ **GIANT JUPITER** remains in Sagittarius all year, so observers should plan to view it when it's highest in the sky, around local midnight these summer nights. *ASTRONOMY:* ROEN KELLY

The Sun pulls a disappearing act

CORONAL STREAMERS dazzle viewers once the Moon completely blocks the Sun's bright photosphere during a total solar eclipse. FRED ESPENAK

For the first time since 1991, nature's finest spectacle graces the North American sky. On August 1, a total solar eclipse occurs just after sunrise in northern Canada.

People in the United States, however, won't see even a partial eclipse. The best observing spots lie on the opposite side of the world.

The eclipse track begins in northern Canada, moves along Greenland's north coast, across the Arctic Ocean, and into Siberia, where totality lasts the longest. The 1.4 million inhabitants of Siberia's biggest city, Novosibirsk, will see 2 minutes and 18 seconds of darkness starting at 3:44 P.M. local time. The Moon's shadow then tracks across Mongolia and China.

Weather conditions vary considerably along the eclipse track, with fewer clouds expected at the Chinese end. In Russia, half or more of August days are cloudy.

As with all total solar eclipses, the Sun's dark umbral shadow follows a narrow path. The Sun appears partially eclipsed over a far broader region, with observers closer to the central line seeing the Moon block a bigger percentage of the Sun.

Most of Europe lies under a partial shadow, excluding Spain, Portugal, and parts of France, Italy, and Greece. From the British Isles, 20 to 40 percent of the Sun will be hidden (more disappears the farther north you go). In Norway and Sweden, the Moon eclipses more than half the Sun.

Anyone who wants to view the partial eclipse needs to use a safe solar filter or project the Sun's image. Severe eye damage or even blindness can result from looking directly at the Sun. You can view an eclipse without a filter only during totality, when the Moon completely blocks the Sun's brilliant disk.

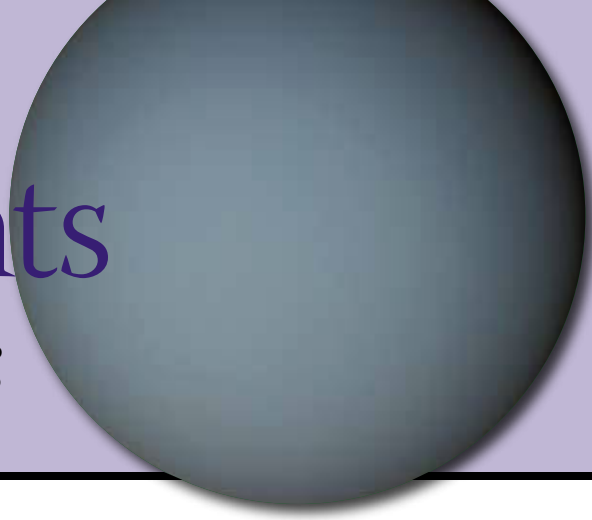
Two weeks after the solar eclipse, on August 16, the Moon enters Earth's shadow for a partial lunar eclipse. Observers in Europe, Africa, and western Asia will see the whole event. Those in South America will see the eclipsed Moon at moonrise, and those in Australia, at moonset.

The partial eclipse begins at 8:36 P.M. British Summer Time (BST) and reaches maximum at 10:10 P.M. BST. The eclipse lasts 188 minutes, ending at 11:44 P.M. BST. At maximum, Earth's dark shadow envelops 81 percent of the Moon. Even though the eclipse falls short of total, observers likely will see at least a hint of color in Earth's shadow.

TOTALITY RULES August 1 along a slim path that begins in northern Canada and ends in China. Observers in most of Europe and Asia will see a partial eclipse. *ASTRONOMY:* ROEN KELLY

01 Total solar eclipse, 6 A.M. EDT
03 The Moon passes 4° south of Saturn, 10 A.M. EDT
04 The Moon passes 4° south of Mars, 8 A.M. EDT
05 Venus passes 1.1° north of Regulus, 4 P.M. EDT
10 Mercury passes 1.1° north of Regulus, 1 A.M. EDT
The Moon passes 0.4° south of Antares, 3 P.M. EDT
12 Perseid meteor shower peaks
13 The Moon passes 3° south of Jupiter, 10 A.M. EDT
Venus passes 0.2° south of Saturn, 3 P.M. EDT
15 Neptune is at opposition, 4 A.M. EDT
Mercury passes 0.7° south of Saturn, 8 P.M. EDT
16 The Moon passes 0.8° north of Neptune, 3 P.M. EDT
Partial lunar eclipse, 5 P.M. EDT
18 The Moon passes 4° north of Uranus, 10 P.M. EDT
23 Mercury passes 1.2° south of Venus, 1 A.M. EDT

Gear up for gas giants



BLAND URANUS didn't show much detail to the Voyager 2 spacecraft, so don't expect to see more than its blue-green color through a backyard scope. NASA/JPL

2008 Sept

S	M	T	W	T	F	S
	1	2	3	4	5	6
◑ 7	8	9	10	11	12	13
14	● 15	16	17	18	19	20
21	◐ 22	23	24	25	26	27
28	○ 29	30				

The solar system's two most distant major planets reach opposition late this summer. Uranus, the seventh planet from the Sun, comes to opposition September 12. Neptune lies opposite the Sun 1 month earlier, on August 15.

You shouldn't have any problem spotting Uranus through binoculars. The 6th-magnitude planet lies in the constellation Aquarius, which becomes visible in the morning sky during April. You can use Phi (ϕ) Aquarii as a guide to the correct field all year.

In early April, binoculars will reveal two 6th-magnitude "stars" east and slightly north of Phi. The eastern one, some 2.8° from Phi, is Uranus. Uranus moves eastward through late June, reaching a point 5° east-northeast of Phi and passing two slightly fainter stars along the way.

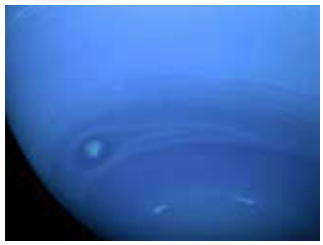
At September's opposition, Uranus lies closest to Earth (1.77 billion miles away) and glows brightest (magnitude 5.7). By November, Uranus passes close to 96 Aquarii, a star slightly brighter than the planet. The pair resembles a wide double star, with 6' separating them in late November. This will be a great time to watch Uranus' motion relative to the background stars of Aquarius — proof it belongs to our solar system.

URANUS AND NEPTUNE lie nearly 30° apart this year. Binoculars will bring both of these distant worlds into view. *ASTRONOMY:* ROEN KELLY

Neptune lies significantly farther west than Uranus, and so comes to opposition before its neighbor. The outer planet lies 2.70 billion miles from Earth at its August 15 peak. It then glows at magnitude 7.8, making it harder to see than Uranus through binoculars.

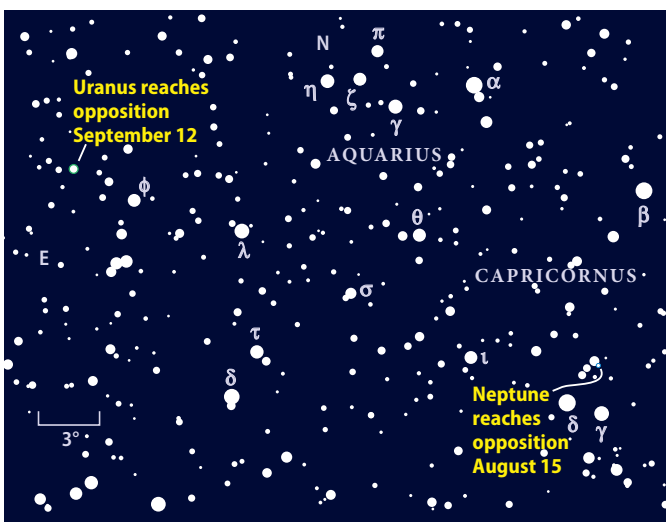
Neptune spends all year among the background stars of Capricornus. Its retrograde loop begins in May, when it lies 3° north of Delta (δ) Capricorni. By July, the planet's westward motion carries it toward a line of three relatively bright stars. The stars — 42, 44, and 45 Capricorni — shine at magnitudes 5.2, 5.9, and 6.0, respectively. During August's first 10 days, Neptune lies between 42 and 44 Cap.

Neptune continues moving westward through early November, when it lies 1.5° west of the three stars. The planet then resumes easterly motion, ending the year within 0.8° of 44 Cap.



NEPTUNE'S SUBTLE CLOUDS intrigued scientists when Voyager 2 flew past, but just seeing the distant planet's disk is enough to please backyard observers. NASA/JPL

Backyard scopes reveal little detail on these giant worlds. Uranus' disk spans 3.7" at opposition and shows a distinct blue-green color. Neptune musters only 2.4" and glows a subtle blue-gray. You can see Uranus' disk at 100x, but Neptune requires higher magnification and good seeing conditions.

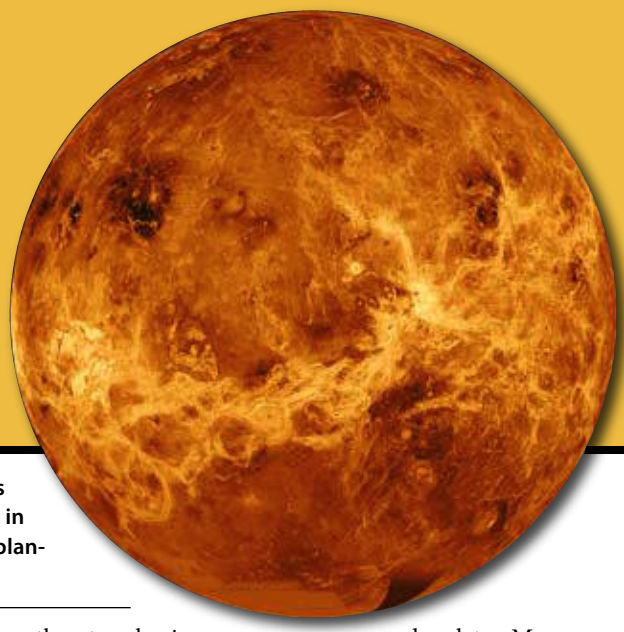


01 The Moon passes 5° south of Venus, 5 P.M. EDT
The Moon passes 3° south of Mercury, 7 P.M. EDT
02 The Moon passes 5° south of Mars, 4 A.M. EDT
03 Saturn is in conjunction with the Sun, 10 P.M. EDT
06 The Moon passes 0.3° south of Antares, 11 P.M. EDT
09 The Moon passes 3° south of Jupiter, 4 P.M. EDT
10 Mercury is at greatest eastern elongation (27°), midnight EDT
11 Mercury passes 4° south of Venus, 1 A.M. EDT
Venus passes 0.3° north of Mars, 5 P.M. EDT
12 Mercury passes 3° south of Mars, 5 P.M. EDT
Uranus is at opposition, 10 P.M. EDT
18 Venus passes 3° north of Spica, 5 A.M. EDT
22 Equinox (northern autumn/southern spring begins), noon EDT
27 The Moon passes 5° south of Saturn, 4 P.M. EDT
30 The Moon passes 5° south of Mars, midnight EDT

2008 Oct

S	M	T	W	T	F	S
			1	2	3	4
5	6	◑	8	9	10	11
12	13	●	15	16	17	18
19	20	◐	22	23	24	25
26	27	○	29	30	31	

Venus rules the twilight skies



VENUS' VOLCANIC PLAINS stand out in this radar mosaic from the Magellan spacecraft; in contrast, earthbound viewers see only the planet's thick clouds. NASA/JPL

The sky's brightest planet always dazzles when it stands clear of the horizon in a twilit or dark sky. The problem for Venus this year is that it never ventures far from the Sun. It experiences no greatest elongations.

The best it can offer — and it turns out to be plenty — are several wonderful conjunctions with other bright planets. In October, you can find it low in evening twilight, climbing toward a magnificent meeting with Jupiter in November.

The year opens with Venus dominating the morning sky. In January, it rises more than 2 hours before the Sun. Then, on February 1, it skims dramatically close to Jupiter, whose brightness is second only to Venus. Venus, gleaming at magnitude –3.9, lies just 0.6° north of Jupiter, shining at magnitude –1.9.

Before dawn February 26, Venus passes 1.3° south of Mercury. The pair pokes above the east-southeastern horizon about an hour before the Sun. The two inner planets remain close as Mercury first loops farther west, then heads east again, passing 1.0° south of Venus March 23.

After Venus passes behind the Sun June 8/9, it begins a long climb into the evening sky. By mid-July, it starts to poke through the twilight shortly after sunset. On August 5, it sets less than an hour after the Sun, but those with an unobstructed horizon might spot Leo's brightest star, Regulus, 1.1° south of the planet. Saturn then trails Venus by 8°.

By August 13, Venus and Saturn lie next to each other, with Mercury climbing to meet them in the western twilight. Venus, shining at magnitude –3.8, lies 0.2° from Saturn, which is dimmer at magnitude 0.8.

Mercury lies 3° to the lower right and has a brightness between the other planets. Two days later, Mercury and Saturn pass 0.7° apart.

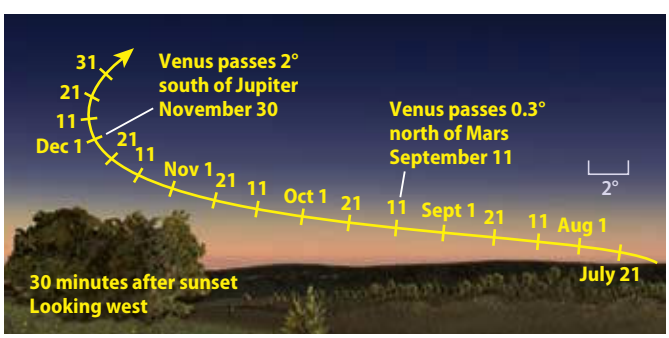
Saturn will be hard to spot in the bright twilight — binoculars will help. A week later, on August 22, Mercury passes 1.2° south of Venus. The pair sets 50 minutes after the Sun.

By September, Venus and Mercury move toward conjunction with Mars. Venus pops into view about half an hour after sunset.

On the 11th, binoculars will reveal Mars, glowing dimly in the twilight at magnitude 1.7, just 0.3° south of Venus. Mercury lies 2.5° below the pair and shines at magnitude 0.1.

Venus starts to show off in late November and December as the ecliptic angles more steeply to the horizon. On November 30, it has a spectacular conjunction with Jupiter.

The next evening, the Moon joins the pair (see December's entry for more details). On December 26, the planet passes 1.5° south of Neptune, a great opportunity to spot the outermost major planet. Neptune glows 12 magnitudes — nearly 100,000 times — fainter than Venus.



VENUS SHINES BRILLIANTLY in the evening sky this autumn and winter, climbing through bright twilight into a dark sky.

ASTRONOMY: ROEN KELLY

- **01** The Moon passes 5° south of Venus, 10 P.M. EDT
- **04** The Moon passes 0.1° south of Antares, 7 A.M. EDT
- **06** Mercury is in inferior conjunction, 5 P.M. EDT
- **07** The Moon passes 2° south of Jupiter, 3 A.M. EDT
- **10** The Moon passes 0.9° north of Neptune, 6 A.M. EDT
- **12** The Moon passes 4° north of Uranus, noon EDT
- **21** Orionid meteor shower peaks
- **22** Mercury is at greatest western elongation (18°), 6 A.M. EDT
- **25** The Moon passes 5° south of Saturn, 4 A.M. EDT
- **26** Venus passes 3° north of Antares, 9 A.M. EDT
- **27** The Moon passes 7° south of Mercury, 2 P.M. EDT
- **29** Asteroid Vesta is at opposition, 10 P.M. EDT
- **30** Mercury passes 4° north of Spica, 4 P.M. EDT
- **31** The Moon passes 0.06° north of Antares, 2 P.M. EDT

Spying stars with extrasolar planets

A SUPER-EARTH, orbiting within its star's habitable zone and likely having a solid surface, orbits the red dwarf Gliese 581. ESO

The dramatic 1995 discovery of a planet orbiting the star 51 Pegasi opened the floodgates. In 2007, astronomers discovered the 250th exoplanet, and the number keeps growing.

Of course, a backyard telescope won't show you any of these planets. Astronomers typically use sensitive spectroscopic devices on large scopes to detect them. Still, it's exhilarating to see one of the host stars directly through a telescope, particularly when you consider its planetary system.

Two of these stars are bright enough to spy with your naked eyes under a dark November sky. First on our list is the first normal star known to possess a planet: 51 Pegasi. This star lies 50 light-years from Earth and shines at magnitude 5.5.

You can find 51 Peg just west of a line joining Markab (Alpha [α] Peg) and Scheat (Beta [β] Peg), the pair of stars that forms the western side of Pegasus' Great Square. Although 51 Peg is similar to the Sun, its Jupiter-like planet orbits once every 4.2 days.

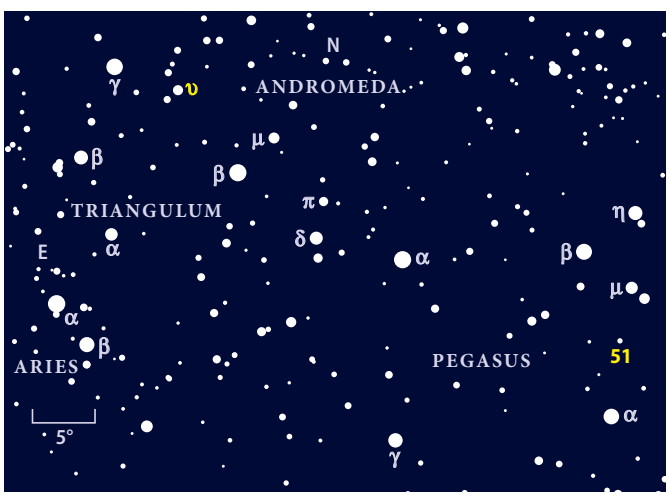
An equally remarkable system exists around Upsilon (υ) Andromedae. This 4.1-magnitude star is a double containing a yellow dwarf and red dwarf. Upsilon And is a snap to find. Start at Almach, Gamma (γ) Andromedae, the famous double star at the constellation's eastern end. Upsilon stands 5° west of Almach.

Astronomers have found at least three planets orbiting Upsilon And. This system was the first known multi-planet system and the first in a system with more than one star.

The innermost planet orbits the star in 4.6 days and weighs slightly less than Jupiter. The second orbits every 242 days and tips the scale at twice Jupiter's mass. The outermost known planet weighs at least 4 Jupiters and takes 3.5 years to complete an orbit.

Our last star is the dim red dwarf Gliese 581, best seen in spring and summer. In early 2007, astronomers discovered two of this star's planets lie in the habitable zone — the region around a star where liquid water can exist — and are only slightly larger than Earth. One of them possesses 8 times Earth's mass, and the other weighs only 5 Earths.

How can you see Gliese 581? It's located just 2° north of Beta Librae, also known as Zubeneschamali. Gliese 581 lies 20 light-years from Earth and glows at magnitude 10.6, bright enough to see in most telescopes. When viewing this star, consider that it could be the target of a future interstellar spacecraft — once our species attains the ability to travel that far.



2008 Nov

S	M	T	W	T	F	S
						1
2	3	4	◑	6	7	8
9	10	11	12	●	14	15
16	17	18	◑	20	21	22
23	24	25	26	○	28	29
30						

01 The Moon passes 3° south of Venus, 4 A.M. EDT

03 The Moon passes 1.9° south of Jupiter, 5 P.M. EST

06 The Moon passes 1.1° north of Neptune, 2 P.M. EST

08 The Moon passes 4° north of Uranus, 8 P.M. EST

17 Leonid meteor shower peaks

21 The Moon passes 6° south of Saturn, 1 P.M. EST

25 Mercury is in superior conjunction, noon EST

30 Venus passes 2° south of Jupiter, 8 P.M. EST

◀ **TWO AUTUMN STARS visible with naked eyes — Upsilon (υ) Andromedae and 51 Pegasi — will delight observers who know they harbor exoplanets.**

ASTRONOMY: ROEN KELLY

2008 Dec

S	M	T	W	T	F	S
	1	2	3	4	◑	6
7	8	9	10	11	●	13
14	15	16	17	18	◐	20
21	22	23	24	25	26	○
28	29	30	31			

Dancing with the planets

BRILLIANT VENUS dominated a still-bright Jupiter (to its upper left) during this conjunction in the summer of 2005. JOE ORMAN

A crescent Moon joins the two brightest planets for a wonderful evening union in early December. Dazzling Venus, which shines at magnitude –4.2, shares the stage with Jupiter, noticeably fainter at magnitude –2.0. On December 1, the two lie only 2° apart, or 4 Moon-widths. A 4-day-old crescent Moon stands 3° east of the stunning pair.

When viewed through a telescope, Venus' disk appears 17" across and 69-percent lit. Compare its phase with the Moon, which appears 15-percent illuminated.

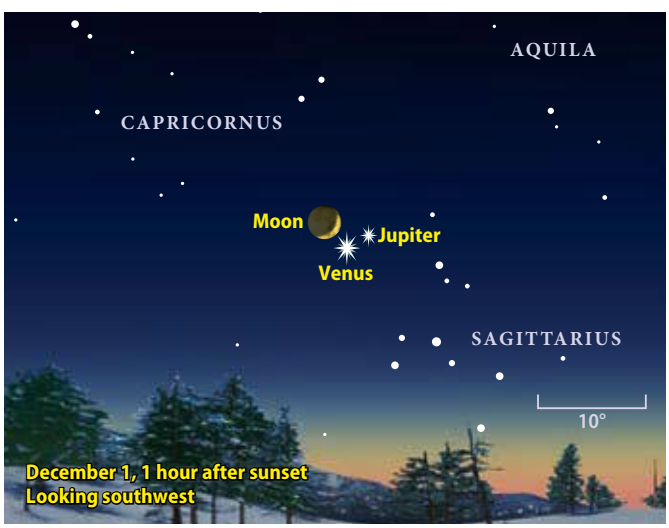
Jupiter, being an outer planet, always displays a fully illuminated disk. With an equatorial diameter of 34", it doubles Venus' apparent size.

As you look at the two, consider that Venus lies 93 million miles from Earth December 1, while Jupiter lies nearly 6 times farther. Jupiter appears so much bigger than Venus because it's 12 times larger.

The two planets lie just a fraction of a degree closer November 30. The scene won't be quite as breathtaking then because the younger Moon lies 8° to Venus' lower right.

During December, Venus climbs higher as it heads toward its January 2009 greatest elongation from the Sun. Meanwhile, Jupiter's angular distance from the Sun declines as it moves toward solar conjunction. On the 5th, the two lie 5° apart, and nearly 10° separate them December 10.

Conjunctions between Venus and Jupiter happen fairly often, although frequently they occur close enough to the Sun that the planets don't appear in a dark sky. The two were close to each other in the morning sky in February 2008. The last nice evening conjunction occurred in September 2005, and the next won't come until March 13, 2012, when the planets will lie 3° apart.



VENUS AND JUPITER, the two brightest planets, meet spectacularly in evening twilight in early December. *ASTRONOMY:* ROEN KELLY

01 The Moon passes 1.3° south of Jupiter, 10 A.M. EST

The Moon passes 0.8° north of Venus, 11 A.M. EST

03 The Moon passes 1.4° north of Neptune, 10 P.M. EST

04 Asteroid Pallas is at opposition, noon EST

05 Mars is in conjunction with the Sun, 5 P.M. EST

06 The Moon passes 4° north of Uranus, 4 A.M. EST

13 Geminid meteor shower peaks

18 The Moon passes 6° south of Saturn, 10 P.M. EST

21 Solstice (northern winter/southern summer begins), 7 A.M. EST

25 The Moon passes 0.09° north of Antares, 2 A.M. EST

26 Venus passes 1.5° south of Neptune, 9 P.M. EST

28 The Moon passes 0.7° north of Mercury, 11 P.M. EST

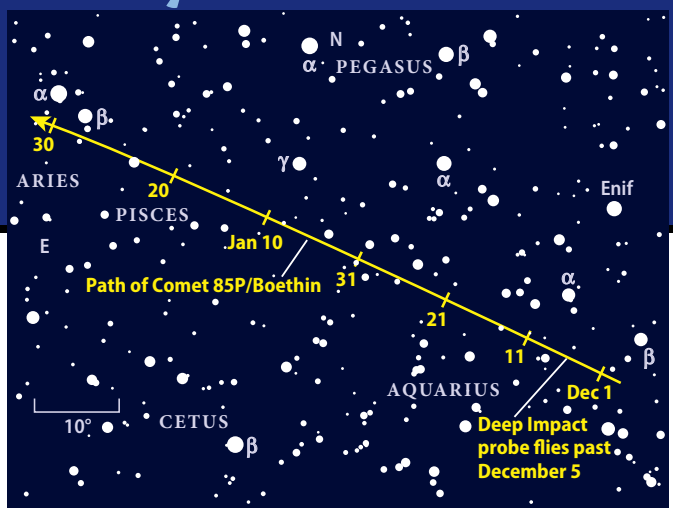
29 The Moon passes 0.6° south of Jupiter, 4 A.M. EST

31 Mercury passes 1.3° south of Jupiter, 1 A.M. EST

The Moon passes 1.7° north of Neptune, 6 A.M. EST

The Moon passes 3° north of Venus, 4 P.M. EST

A worthy comet returns to view



COMET 85P/BOETHIN should peak around 7th magnitude in December and January, when you can find it among the stars of Aquarius and Pisces. *ASTRONOMY:* ROEN KELLY

Comet 85P/Boethin should reach 7th magnitude in late 2008 and early 2009. This places the comet within easy reach of tripod-mounted binoculars.

The comet crosses northern Capricornus and moves into Aquarius during early December, when it rides high in the evening sky. The object's path then carries the dirty ice ball across Pisces in late December and most of January. It sits still higher then in the evening sky and sets around midnight.

Even 7x50 binoculars will reveal the comet as a tiny smudge of light throughout this period. Boethin makes its closest approach to Earth December 23, when it lies 81 million miles away.

Comet Boethin receives a visitor from Earth December 5, when the remaining spacecraft from the Deep Impact mission flies past. Deep Impact visited Comet 9P/Tempel 1 in July 2005. An impactor smashed into the comet's nucleus, producing a brief cometary "fireworks" display studied by the flyby spacecraft and observers around the globe. The flyby probe now moves into the Deep Impact Extended Investigation, which will monitor Comet Boethin with two color cameras and an infrared spectrometer.

Discovered from the Philippines by the Reverend Leo Boethin in January 1975, this comet orbits the Sun once every 11.5 years. Astronomers observed it during its 1986 apparition but missed it during the unfavorable 1997 return. The prospect of a favorable apparition combined with a visiting spacecraft will make this comet a popular target for backyard observers as 2008 winds down and 2009 begins.

COMET 9P/TEMPEL 1 posed for the Deep Impact spacecraft in July 2005. The same probe will fly past Comet 85P/Boethin in December 2008. NASA/JPL/UMD

2009 Jan

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11	12	13	14	15	16	◐
18	19	20	21	22	23	24
25	○	27	28	29	30	31

- 02 The Moon passes 5° north of Uranus, noon EST
- 03 Quadrantid meteor shower peaks
- 04 Mercury is at greatest eastern elongation (19°), 9 A.M. EST
- 14 Venus is at greatest eastern elongation (47°), 4 P.M. EST
- 15 The Moon passes 6° south of Saturn, 7 A.M. EST
- 18 Asteroid Juno is in conjunction with the Sun, 5 P.M. EST
- 20 Mercury is in inferior conjunction, 11 A.M. EST
- 21 The Moon passes 0.02° north of Antares, 8 A.M. EST
- 23 Venus passes 1.4° north of Uranus, 11 A.M. EST
- 24 Jupiter is in conjunction with the Sun, 1 A.M. EST
- 26 Annular solar eclipse, 3 A.M. EST
- 27 The Moon passes 1.8° north of Neptune, 1 P.M. EST
- 29 The Moon passes 5° north of Uranus, 8 P.M. EST
- 30 The Moon passes 3° north of Venus, 7 A.M. EST

2009 PREVIEW

Looking ahead to next year...

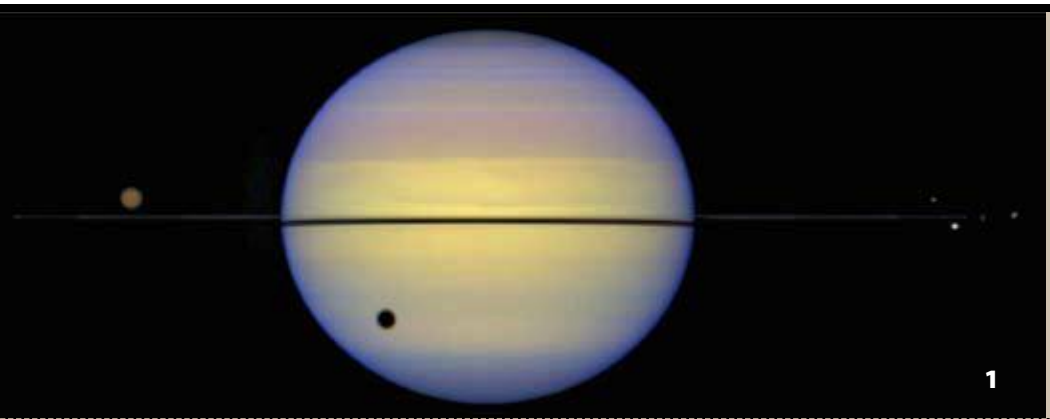
The year gets off to a smashing start. Venus, a jewel in the evening sky, contrasts nicely with Comet 85P/Boethin's binocular return. The good views just keep on coming.

Among the planets, Venus rules the year. It's the "evening star" until mid-March, then it swings past the Sun and becomes a morning fixture through November. And asteroid Ceres appears brighter in 2009 than it has in 5 years.

But 2009's biggest planetary event comes from Saturn, which turns its rings edge-on to our line of sight for the first time in 14 years. Although the rings' absence means Saturn won't be its usual telescopic wonder, we'll get exceptional views of the planet's disk and interactions among its moons.

As far as lunar eclipses go, 2009 offers quantity over quality. Although four eclipses occur, the Moon passes into Earth's dark umbral shadow only once. Even then, less than 10 percent of the Moon will darken.

The total solar eclipse of July 21/22 makes up for the lack of good lunar eclipses. More than 5 minutes of totality await observers along the center line as it cuts through China, and the Sun will disappear for nearly 6 minutes and 40 seconds when the eclipse peaks in the western Pacific.



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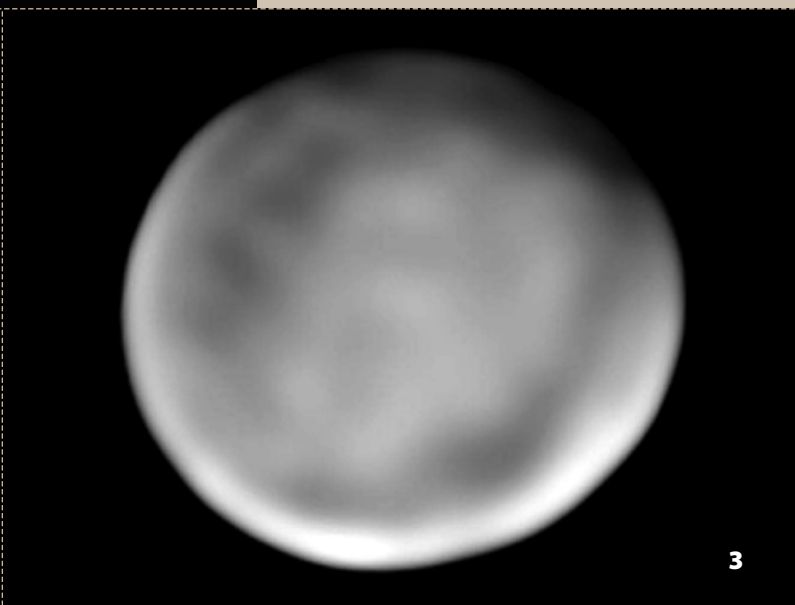

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1 SATURN'S RINGS will "disappear" in 2009 when they turn edge-on to our line of sight for the first time in 14 years. ERICH KARKOSCHKA (LPI)/NASA

2 TOTALITY RETURNS July 21/22, when parts of eastern Asia and the Pacific will see the Sun disappear for more than 5 minutes. MARTIN RATCLIFFE

3 ASTEROID CERES reaches the peak of its current apparition in February, when it glows at 7th magnitude and will be easy to see through binoculars. KECK OBSERVATORY/C. DUMAS (NASA/JPL)